

Aedes taeniorhynchus and *Ae. sollicitans* (DIPTERA: CULICIDAE) OVIPOSITION ON COASTAL DREDGE SPOIL¹

G. L. SCOTTON AND R. C. AXTELL

North Carolina State University, Raleigh, NC 27650, USA

ABSTRACT. The distribution of *Aedes sollicitans* (Walker) and *Ae. taeniorhynchus* (Wiedemann) eggs on 3-yr-old diked dredge spoil disposal areas in coastal North Carolina was monitored from March through September, 1976. The eggs were extracted by sieving and flotation from soil samples (15 × 15 × 2 cm) collected every 1–3 weeks from each of 4 major habitats (bare mud, new *Aster*, old *Aster* and shrub) on each of 4 disposal areas.

Overall, most (ca. 90%) of the eggs found were those of *Ae. taeniorhynchus*. However, 10% of the eggs from March to September and 26% in late September were those of *Ae. sollicitans*.

INTRODUCTION

The dredging of bottom sediments from harbors and waterways creates a need for dredge spoil disposal sites. Hydraulic dredging is the principal method used in North Carolina. Since the early 1970's, the dredged material has been placed within dikes to prevent siltation into adjacent waters. The time between successive additions of dredge spoil to a site depends on the rate of siltation in adjacent waters. These diked dredge spoil sites develop several distinct vegetative zones after 2–3 years.

We have observed that many of the diked dredge spoil areas are breeding habitats for *Aedes* mosquitoes. A dredge disposal site is prepared by digging out peripheral sediments which are used in dike formation. This creates a circumferential ditch inside the dike. Dredged material is pumped to the center of the

Although the distribution of mosquito eggs among the major habitats varied among the disposal sites, the overall order of habitats based on egg densities on all sites was (least to most): bare mud, shrub, old *Aster* and new *Aster*. The majority of eggs found were in surface root mats of the new *Aster* zone. Soil cracks contained medium densities of eggs in all habitats and most of the eggs were on the top 10 cm of the crack walls. Very few eggs were found on soils which were covered by a thin algal film. Egg density throughout the season was related to fluctuations in rainfall and standing water level.

spoil site. Larger particles settle near the center; fine silt particles are carried to the poorly drained peripheral ditches. This results in a moist soil surface ideal for oviposition by *Aedes* mosquitoes. Soils settling in better drained regions of the island dry and contract which results in the formation of a network of soil cracks. Cracks can be up to 45 cm deep and 10 cm wide. In the deepest cracks, standing water can persist after a rainfall when the islands are otherwise dry. This allows larvae to complete development. Whether the moist crack walls are suitable oviposition sites is not known, but observations of numerous adult mosquitoes resting on these crack walls led to the suggestion that they are preferred oviposition sites (Murphy and Ziegler 1974, O'Meara 1976).

The objective of this investigation was to determine egg densities of *Ae. sollicitans* and *Ae. taeniorhynchus* in the different vegetative zones found on dredge spoil.

METHODS

Four 3-yr-old diked dredge spoil sites along the intracoastal waterway in Onslow County, North Carolina, were sampled.

¹ This research was supported by NOAA, office of Sea Grant, U.S. Dept. of Commerce, under Grant No. 04-3-58-40 and the North Carolina Dept. of Administration. Paper No. 5702 of the Journal Series of the North Carolina Agricultural Station, Raleigh, NC.

They were designated as Nos. 4, 5, 7, 8. Numbers 5 and 7 were distinct islands (29 and 13 acres, respectively). Spoil area 4 (21 acres) was located on Topsail Island. Area 8 (12 acres) was located on the mainland.

Four distinct vegetative zones were found on each dredge spoil site (Fig. 1). The lowest and wettest elevations consisted of only bare mud or mud bearing scattered algal growth. These bare mud

zones were surrounded by areas densely vegetated with *Aster subulatus* Michx. Typically, this "new" *Aster* zone was in extremely wet soils where no vegetation had been present the previous year. Adjacent to this new *Aster* zone was an "old" *Aster* zone where dead *Aster* plants from previous seasons were intermingled among the present season's *Aster* growth. *Spartina cynosuroides* L., *Solidago* spp., *Cyperus* spp., and *Sabatia* spp. were also present.

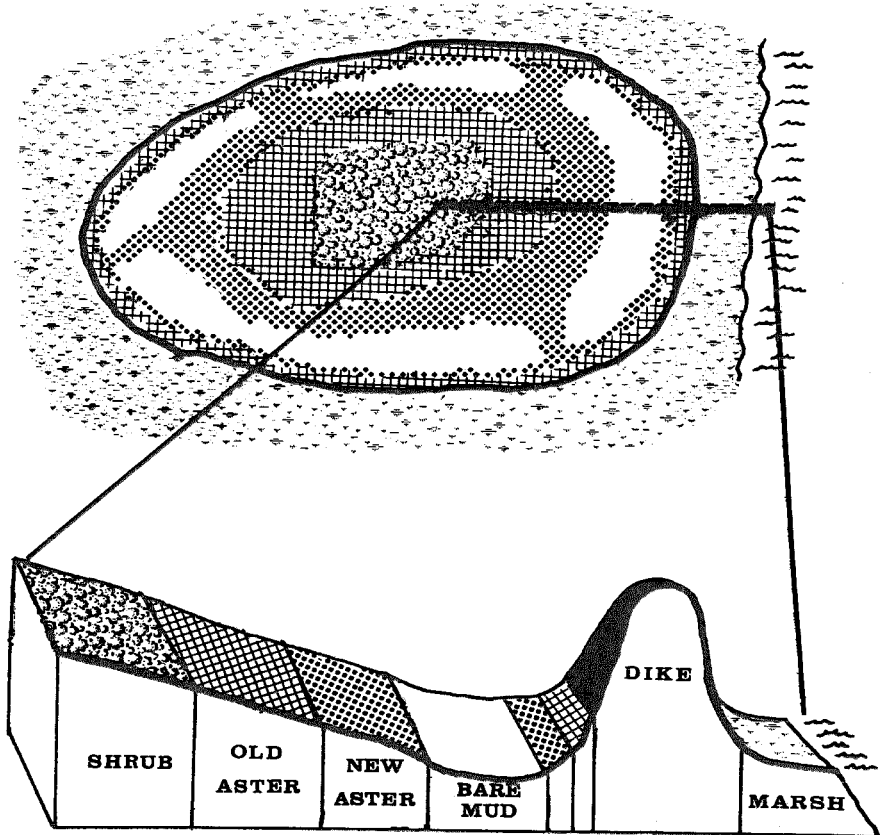


Fig. 1. Diagram showing major habitats in a diked dredge spoil site adjacent to a water way. Upper: aerial view. Lower: sagittal section showing relative elevations of habitats.

In the more sandy, dry and higher elevations, dead and living shrubs and trees were the dominant forms of vegetation. *Rubus* spp., *Rhus* spp., *Iva frutescens* L., *Myrica cerifera* L. and *Baccharis halimifolia* L. were common.

A sampling area containing all 4 of the distinct vegetative zones was chosen on each site. Soil samples were taken from each of these zones every 2-3 weeks on sites 4 and 8. On No. 4, samples were taken from March 23 to September 8. No. 8 was sampled until August 3. Sites 5 and 7 were sampled on June 15 and September 29. On each sampling date, 10 samples were taken from each of the 4 major habitats. On July 22, 69 samples were taken from soil cracks 30 cm deep on site No. 7. Samples were taken at depths of 0-10, 10-20, and 20-30 cm in both new *Aster* and old *Aster* zones. In addition, on August 5, 55 samples were taken from the bare cracked soil of two 3-month-old spoil areas in Brunswick County, North Carolina.

A habitat submerged at the time of sampling was recorded as 0 eggs/sample since the soil surface was not available for oviposition. A habitat frequently unavailable for oviposition would receive a small proportion of the total egg population. Consequently, it could be considered less important as an ovipositional site. The bare mud habitat was flooded on 5 of the 11 sampling dates on site 4, 1 of the 2 sampling dates on site 5, 2 of the 2 sampling dates on site 7 and 4 of the sampling dates on site 8. The new *Aster* zone of site No. 8 was flooded on 1 sampling date. The other zones were not flooded on any of the sampling dates. Since extremely low egg densities existed in all bare mud samples collected throughout the season the recording of a flooded site as 0 eggs did not distort the data. The mean number of whole eggs collected per sample during this study on sites 4, 5 and 8 respectively were 3.0, .1 and .3. The corresponding mean numbers of hatched eggs were 1.6, .2 and .7.

Because of the assumption that eggs are laid on the walls of the soil cracks, we

took, prior to July 28, all samples from the walls of the soil cracks in each of the 4 major habitats. Data from the first 5 months of sampling of the crack walls in the 4 major habitats showed that the new *Aster* and old *Aster* zones yielded the most eggs. Therefore, additional samples were taken from the microhabitats in these 2 zones. The new *Aster* zone was differentiated into (1) rootmat covered soil surfaces, (2) algae covered crack walls and (3) bare crack walls. The old *Aster* was divided into (1) surface soil and (2) crack wall microhabitats. On August 17 and September 8, 10 samples were taken from each microhabitat on site 4. On September 29, 10 samples were taken from similar microhabitats on sites 5 and 7. The sampling of the cracks in the bare mud and shrub zones was continued on these dates.

Each sample was ca. $15 \times 15 \times 2$ (450 cm³). The sampling tool was a 15×15 cm stainless steel tray with 3 sides upturned to a height of 5 cm and the 4th side protruded as a 5 cm lip. We used this tray to sample cracks after removing one wall of the crack. The open side of the tray was forced into the remaining crack wall and the soil scraped into the tray with a trowel. To sample the surface soil, the lip of the tray was inserted 2 cm below the surface and then pushed horizontally to obtain the sample.

Eggs were extracted from the soil samples by a flotation method modified from Salt and Hollick (1944), Horsfall (1956) and Service (1968). The soil samples, unless sufficiently crumbled, were broken up in water in an electric blender for 15 sec. The blender blades were covered with rubber tubing to reduce the risk of damaging the eggs. Each sample was then rinsed through a No. 30 (595 μ m, 10 mesh/cm) and No. 80 (177 μ m, 31 mesh/cm) sieve. Soil remaining in the No. 80 sieve was rinsed into a 100 ml plastic beaker with a 1.1 sp. gr. solution of magnesium sulfate (Salt and Hollick 1944). The solution was stirred and allowed to settle. All floating eggs and detritus were poured onto a 40 mesh/cm screen. In

order to prevent the floating material (including eggs) from adhering to the back wall of the beaker during the pour-off, water was slowly pumped through tubing into the beaker and beneath the water surface to provide a slight surface agitation. The top edge of the beaker was wiped with a cotton swab, which was rinsed over the screen. The screen was examined under a stereoscope at a magnification of 6-12X and the eggs counted and removed for species determination. Identifications were made at magnifications of 100X after placing the eggs on depression slides which had been covered with black electrician's tape (Horsfall 1956). When eggs became very abundant, species determinations were made only on a subsample. To test the efficiency of the recovery procedure, 10 eggs were added to an egg-free soil sample and the standard recovery procedure followed. With 10 trials, the egg recovery was $71 \pm 8\%$ and 8.5% of the recovered eggs were damaged. None of the eggs hatched during the extraction process. Data in this report were not corrected for this recovery efficiency rate.

The mosquito eggs recovered in this investigation have been previously described (Horsfall et al. 1952, Horsfall and Craig 1956, Craig and Horsfall 1960). Horsfall et al. (1970), Matsuo et al. (1974) and Olson and Meola (1976) described techniques for scanning electron microscopy of mosquito eggs. The eggs of *Ae. sollicitans* and *Ae. taeniorhynchus* are elongate obovoid to broadly fusiform (Fig. 2). The dorsal side is straighter than the concave ventral side. *Ae. sollicitans* eggs are $729 \pm 17 \mu\text{m} \times 221 \pm 14 \mu\text{m}$ and can be recognized by surface sculpturing that bears lateral arms. *Ae. taeniorhynchus* is $746 \pm 7 \mu\text{m} \times \pm 15 \mu\text{m}$ and bears caudally-armed sculpturing.

A few eggs of *Ae. atlanticus* Dyar and Knab and *Psorophora ciliata* (Fabricius) were found. *Ae. atlanticus* eggs can be recognized by their almost diamond-shaped profile and distinct anterior and posterior sculpturing. Mean size is $972 \pm 9 \mu\text{m} \times 288 \pm 5 \mu\text{m}$. *Ps. ciliata* eggs are more

robust and football-shaped. The surface is hexagonally punctate. Egg dimensions are $822 \pm 25 \mu\text{m} \times 421 \pm 13 \mu\text{m}$.

Records were kept of both whole and hatched eggs. Since no mosquito larvae were found among the detritus extracted, hatched eggs were considered to be representative of past mosquito populations and whole eggs representative of future populations.

Rain gauges were set up on each sample site. Fluctuations in standing water level were monitored throughout the season by placing a stake labeled in measured increments near the center of each pool.

Sampling design was $4 \times 4 \times 13$ factorial. The data from the 4 islands, 4 habitats and 13 sampling dates included in the study were treated as a $4 \times 4 \times 13$ incomplete factorial. The analysis of variance was performed using a regression program because of the missing data. The total number of eggs per set of 10 samples per date was used for each habitat and microhabitat. Prior to analysis, all data were transformed to the $\sqrt{x+1}$ (Bartlett 1947). An analysis of variance and a regression procedure were performed on all data. Least significant differences were determined where appropriate. Data from the July 22 samples in the crack depth study and from the August 5 samples from the 3-month-old site were not included in this analysis.

RESULTS AND DISCUSSION

In addition to thousands of *Ae. taeniorhynchus* and *Ae. sollicitans* eggs, 32 *Ae. atlanticus* and 14 *Ps. ciliata* eggs were found. *Ae. atlanticus* eggs were found only when sampling cracks which were greater than 30 cm deep. The eggs were found at all depths in these cracks. Cracks of this depth were of the same surface width (10 cm) as shallower cracks. *Ps. ciliata* eggs were found only on September 29 and were mostly from the old *Aster* zone. The numbers of *Ae. atlanticus* and *Ps. ciliata* eggs recovered were too few to justify any analysis or interpretation.

An analysis of variance was performed on the numbers of *Ae. taeniorhynchus* and *Ae. sollicitans* eggs recovered. Differences in egg densities were significant among the 4 major habitats (bare mud, new *Aster*, old *Aster*, and shrub) as well as among the 4 dredge spoil sites and among the differ-

ent sampling dates. Slight differences in habitat which existed on each of the 4 sites (habitat \times site interactions) and slight habitat differences which occurred on different dates (time \times habitat interactions) also resulted in significant differences in egg densities.

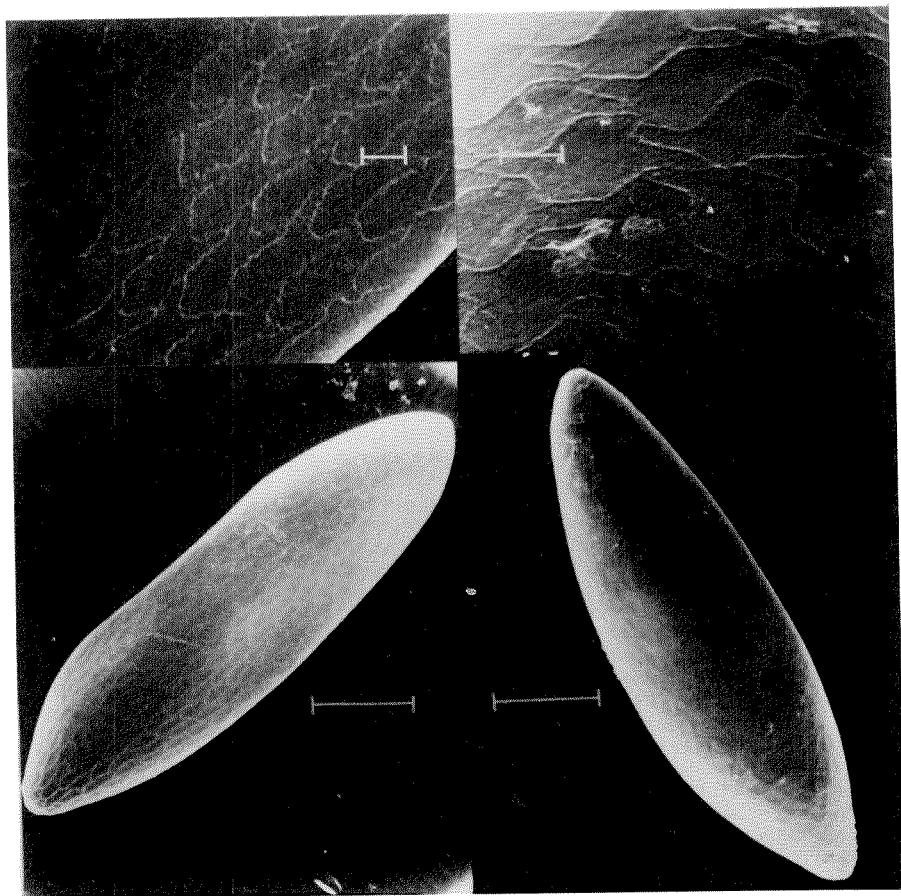


Fig. 2. Scanning electron micrographs of mosquito eggs.

Left: *Aedes taeniorhynchus* (lower: whole egg; upper: close-up of chorionic sculpturing). Right: *Aedes sollicitans* (lower: whole egg; upper: close-up of chorionic sculpturing). Scale bars = 100 μ for whole eggs and 10 μ for chorionic sculpturing close-ups.

The numbers of eggs in soil samples collected from crack walls from March 23–August 17, prior to microhabitat sampling, suggested ovipositional preference for the new *Aster* zone. Both sites No. 4 and No. 8 had been sampled 9 times prior to August 17. On site No. 4, the majority of eggs were found in the 2 *Aster* zones with the new *Aster* zone containing considerably more eggs than did the old *Aster* zone. On site No. 8, however, about equal egg densities were found in the new *Aster*, old *Aster*, and shrub zones. The bare mud yielded few eggs from either site. Sites 5 and 7 were each sampled once prior to microhabitat sampling and the 2 *Aster* zones contained the majority of eggs on both sites with the new *Aster* zone containing the greatest egg densities. Thus, on sites 4, 5, and 7 the order of habitat preference (from least to most) was bare mud, shrub, old *Aster* and new *Aster*. The slope and elevation of the old *Aster* zone sampled on site 7, September 29, was much greater than those typical of the old *Aster* zone and in this case the egg density was greater in the old *Aster* zone than in the new *Aster* zone. The much higher elevation of the old *Aster* area may have permitted eggs to accumulate longer between floodings than occurred elsewhere on the spoil sites. An analysis of the soil in each habitat showed no correlation between egg density and pH (range 4.1–9.6) or % organic matter (range 3.9–6.9).

In spite of these variations in egg densities per habitat, in general, the *Aster* zones contained the greatest number of eggs, and usually there were more in the new *Aster* than in the old. The data (transformed to $\sqrt{x+1}$ prior to analysis) for the egg densities for the 4 habitats for each of the 4 dredge spoil sites for the entire sampling period (March 23–September 29) are presented in Table 1.

To accommodate the variation which existed between sites, the habitats on each site were ranked 1–4 according to the egg densities to express the overall ovipositional importance of each habitat (1 = least preferred, 4 = most preferred) (Table 2). When all sites and sample dates

were considered, both *Ae. taeniorhynchus* and *Ae. sollicitans* whole and hatched eggs displayed the same overall pattern of abundance (from least to most): namely, (1) bare mud, (2) shrub, (3) old *Aster*, and (4) new *Aster*. The distinction between old and new *Aster* was slight.

The numbers of eggs recovered were low, and the overall differences among habitats were minor or not significant on dredge spoil site no. 8. Therefore, sampling of the microhabitats within the *Aster* zones was conducted on sites 4, 5, and 7 during August and September. Analysis of variance ($\sqrt{x+1}$ transformation) showed that the numbers of eggs (both whole and hatched) of both *Ae. taeniorhynchus* and *Ae. sollicitans* were significantly different among the 3 microhabitats in the new *Aster* zone and differed significantly among the different sampling dates. In the old *Aster* zone, the numbers of eggs were generally lower and differences between the 2 microhabitats were significant with the majority of eggs being found on the soil surface. The number of whole and hatched eggs of both species differed significantly among the sampling dates.

The results of the microhabitat sampling are given in Fig. 3 and Table 3. Most of the eggs were recovered in the new *Aster* zone and within that zone the surface root mat microhabitat contained the greatest densities of eggs (whole and hatched) of both species. The sides of cracks contained the second highest densities. Comparing the numbers of hatched versus whole eggs of *Ae. taeniorhynchus*, there were more hatched eggs in the surface root mat than in the cracks while the numbers of whole eggs was similar in both microhabitats (although there was a significant difference). For *Ae. sollicitans* there were about equal numbers of hatched and whole eggs in the root mat. The algae-lined walls of the soil cracks yielded very few eggs, either hatched or whole, for either species. In the old *Aster* zone, the densities of eggs was greater on the soil surface than in the cracks.

The microhabitat study showed that

Table 1. Densities of eggs (whole or hatched) of *Aedes taeniorhynchus* and *Aedes sollicitans* in 4 major habitats on each of 4 dredge spoil sites, Onslow County, North Carolina, March 23–September 29, 1976.

| Habitat | No. Sample Dates | Mean No. eggs ^a | | | |
|-----------|------------------|----------------------------|---------|-----------------------|---------|
| | | <i>A. taeniorhynchus</i> | | <i>A. sollicitans</i> | |
| | | whole | hatched | whole | hatched |
| | | | | <i>Site No. 4</i> | |
| Bare mud | 11 | 12.6 a | 6.8 a | 3.5 a | .4 a |
| New Aster | 11 | 334.8 b | 244.8 b | 5.4 a | 10.4 b |
| Old Aster | 11 | 55.5 c | 167.0 b | 9.4 a | 4.2 c |
| Shrub | 11 | 172.3 c | 55.1 c | .6 a | 6.1 cb |
| | | | | <i>Site No. 5</i> | |
| Bare mud | 1 | 1 a | 0 a | 0 a | 0 a |
| New Aster | 2 | 462.5 b | 179.0 b | 20.5 b | 11.5 b |
| Old Aster | 2 | 100.0 a | 110.5 b | 14.5 a | 12.0 b |
| Shrub | 1 | 13.5 a | 12.0 a | 2.0 a | 3.5 ab |
| | | | | <i>Site No. 7</i> | |
| Bare mud | 1 | 0 a | 0 a | 0 a | 0 a |
| New Aster | 2 | 129.5 b | 294.5 b | 49.5 b | 98.5 b |
| Old Aster | 2 | 448.0 b | 307.0 b | 6.5 a | 31.0 c |
| Shrub | 1 | 3.0 a | 2.0 a | 0 a | 0 a |
| | | | | <i>Site No. 8</i> | |
| Bare mud | 9 | .9 a | 3.0 a | .3 a | .1 a |
| New Aster | 9 | 13.9 a | 25.1 b | 1.6 a | 6.1 a |
| Old Aster | 9 | 16.6 a | 19.4 bc | .8 a | 4.9 bc |
| Shrub | 9 | 17.2 a | 20.4 ac | 1.8 a | 2.3 ac |

^a Means based on total nos. of whole or hatched eggs recovered from a set of 10 soil samples (1 sample = 450 cm³) from each habitat on each sampling date. Data were transformed to $\sqrt{x+1}$ prior to statistical analysis. Means followed by the same letter within each column for each site were not significantly different (LSD_{.05}).

Table 2. Ranked order of habitat preference for oviposition by *Aedes taeniorhynchus* and *Aedes sollicitans* based on the densities of whole and hatched (in parentheses) eggs recovered from all soil samples taken on 4 dredge spoil sites, March–September 1976, Onslow County, North Carolina. 1 = least preferred, 4 = most preferred.

| Habitat | Preference rank/site no. | | | | Mean Rank |
|-----------|--------------------------|------|----------|------|-----------------------------|
| | 4 | 5 | 7 | 8 | |
| | | | | | |
| | | | | | <i>Aedes taeniorhynchus</i> |
| Bare mud | 1 (1) | 1(1) | 1 (1) | 1(1) | 1.0(1.0) |
| New Aster | 4 (4) | 4(4) | 3 (3) | 3(4) | 3.5(3.7) |
| Old Aster | 2 (3) | 3(3) | 4 (4) | 3(3) | 3.0(3.2) |
| Shrub | 3 (2) | 2(2) | 2 (2) | 3(2) | 2.5(2.0) |
| | | | | | <i>Aedes sollicitans</i> |
| Bare mud | 2 (1) | 1(1) | 1.5(1.5) | 1(1) | 1.4(1.1) |
| New Aster | 3.5(4) | 4(3) | 4 (4) | 3(4) | 3.6(3.7) |
| Old Aster | 3.5(2) | 3(4) | 3 (3) | 2(3) | 2.6(3.0) |
| Shrub | 1 (3) | 2(2) | 1.5(1.5) | 4(2) | 2.1(2.1) |

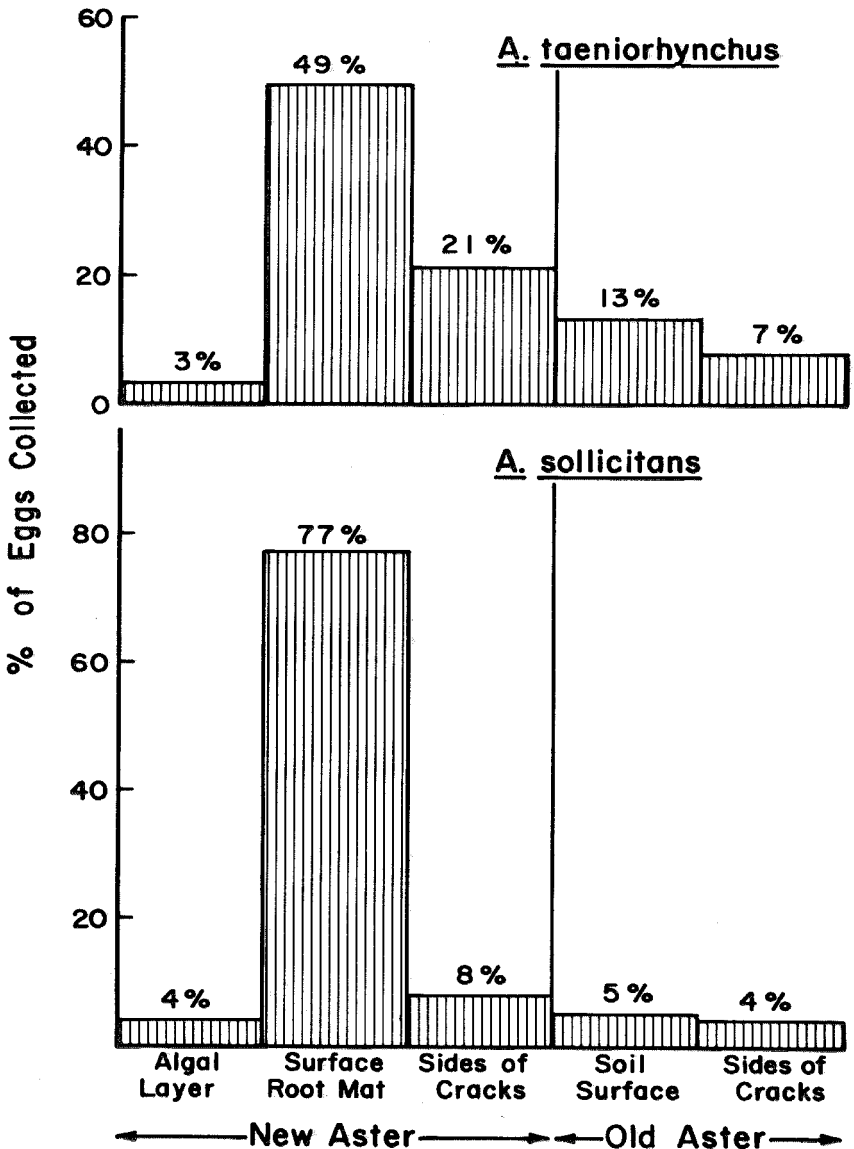


Fig. 3. Percentage of total eggs (whole and hatched) of *Aedes taeniorhynchus* and *Aedes sollicitans* recovered from each microhabitat in the new *Aster* and old *Aster* zones on diked dredge spoil sites. (40 samples per microhabitat, August 15–September 29, 1976.)

Table 3. Densities of eggs (whole or hatched) of *Aedes taeniorhynchus* and *Aedes sollicitans* in microhabitats in zones of new and old *Aster subulatus* in dredge spoil sites nos. 4, 5, and 7, Onslow County, North Carolina, 1976.

| Microhabitat | No. Samples | Mean No. eggs ^a | | | |
|--------------|-------------|----------------------------|------------------|-----------------------|---------|
| | | <i>A. taeniorhynchus</i> | | <i>A. sollicitans</i> | |
| | | whole | hatched | whole | hatched |
| | | | <i>New Aster</i> | | |
| Algae | 40 | 147.0 a | 134.3 a | 26.5 a | 18.0 a |
| Root mat | 37 | 985.6 b | 2787.3 b | 358.5 b | 452.5 b |
| Cracks | 40 | 1006.3 c | 613.5 c | 37.8 c | 51.0 c |
| | | | <i>Old Aster</i> | | |
| Surface | 40 | 429.8 a | 625.0 a | 24.8 a | 30.3 a |
| Crack | 40 | 324.8 b | 253.3 b | 31.3 b | 15.0 b |

^a Means based on total no. of whole or hatched eggs recovered from a soil sample (450 cm²). Data were transformed to $\sqrt{x+1}$ prior to statistical analysis. Means followed by the same letter within each column for each zone were not significantly different (LSD_{.05}).

few or no mosquito eggs were present on crack walls covered with algae. Species of algae present were *Oscillatoria formosa* Bory, *Anabaena variabilis* Kutzing, *Frustulia* sp. and *Gyrosigma* sp. Another type of algal mat was commonly found on dredge spoil where semipermanent pools had evaporated. This mat was comprised of *Oedogonium* sp., *Anabaena variabilis* Kutzing, and few pennate diatoms. Ten samples taken from such a mat on September 29 yielded only 1 whole and 11 hatched eggs. The possibility that the presence of these algae deters oviposition should be explored.

Fig. 4 shows the results of the crack depth study. The numbers of *Ae. taeniorhynchus* eggs on a vertical soil wall decreased with increased depth of the crack. In both the new *Aster* and old *Aster* zones, whole and hatched eggs were most dense in the top 10 cm. The number of hatched eggs at the 10–20 cm depth exceeded the number of whole eggs at this depth. Old *Aster* cracks contained a higher whole egg density than did new *Aster* cracks. Few eggs were found at the deepest depths of 20–30 cm. Too few eggs of *Ae. sollicitans* were recovered for any interpretation of the data.

The 55 samples taken from the two 3-month-old dredge islands contained only 14 whole and 4 hatched *Ae. taeniorhynchus* eggs.

As shown in Table 4, late in the season there was an increase in number of eggs of *Ae. sollicitans*. From August 17 to September 29, the mean number of both whole and hatched *Ae. sollicitans* eggs/sample/microhabitat increased significantly. The mean number of both whole and hatched *Ae. taeniorhynchus* eggs/sample/microhabitat decreased sharply from September 8 to September 29 in both new and old *Aster* zones, while the number of whole *Ae. sollicitans* eggs decreased similarly in the old *Aster* zone but increased in the new *Aster* zone.

From March 23 to September 8, *Ae. sollicitans* eggs comprised less than 11% of the total egg population per sample date with the exception of samples taken on May 25 which contained 23% *Ae. sollicitans* eggs. Of the 80 samples taken on this date, 70 whole *Ae. taeniorhynchus* eggs and 21 whole *Ae. sollicitans* eggs were found. Fourteen of the *Ae. sollicitans* eggs were found in 1 sample. In the remaining 79 samples, *Ae. sollicitans* comprised 10% of the total egg population. In 80 additional samples taken on May 25 for laboratory flooding, none of the hatched larvae were *Ae. sollicitans*.

The data collected in September suggest that the proportion and distribution of *Ae. sollicitans* eggs increases late in the season. On September 29, the final sample date, more than 26% of the eggs

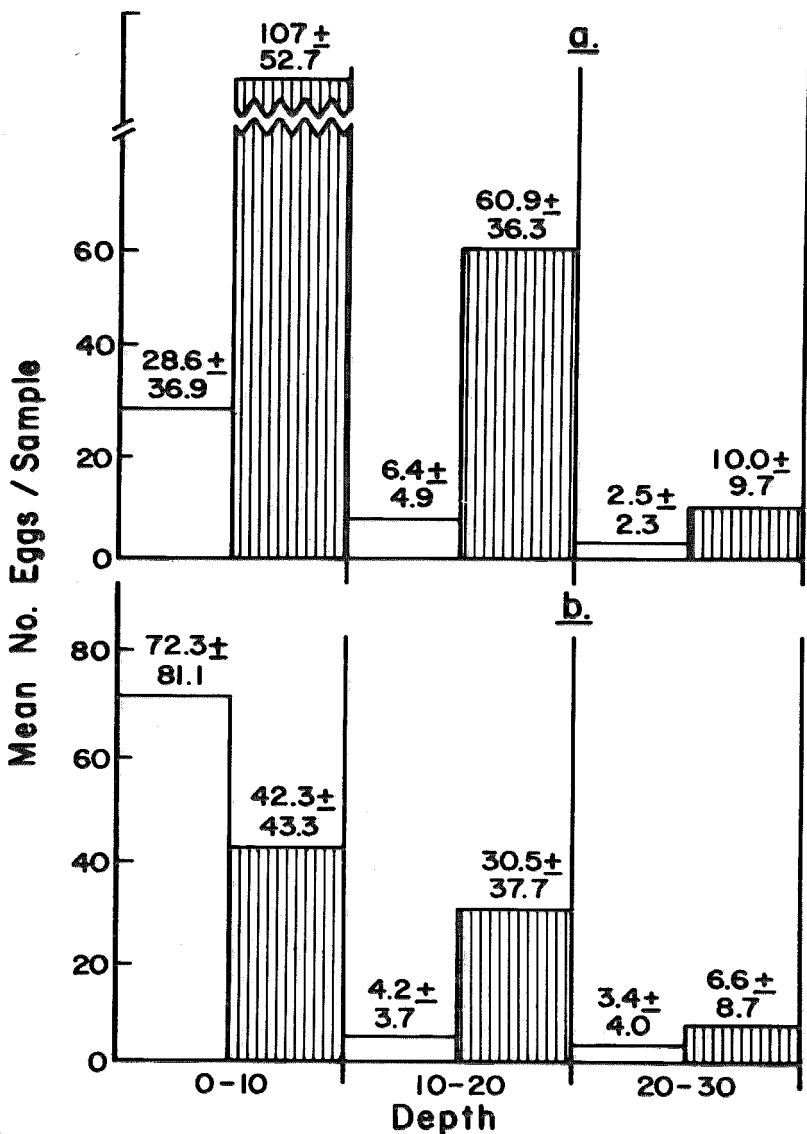


Fig. 4. Mean no. per sample of whole (plain bar) and hatched (stripped bar) eggs of *Aedes taeniorhynchus* recovered from soil cracks at 3 depth intervals (cm) in the new Aster (a, upper) and old Aster (b, lower) zones of dredge spoil site No. 7. July 28, 1976.

Table 4. Densities of eggs (whole or hatched) of *Aedes taeniorhynchus* and *Aedes sollicitans* late in the season in zones of new and old *Aster subulatus* on dredge spoil sites nos. 4, 5, and 7, Onslow County, North Carolina, 1976.

| Sampling Date | No. Samples | Mean no. eggs ^a | | | |
|---------------|-------------|----------------------------|---------|-----------------------|---------|
| | | <i>A. taeniorhynchus</i> | | <i>A. sollicitans</i> | |
| | | whole | hatched | whole | hatched |
| | | | | <i>New Aster</i> | |
| Aug. 17 | 30 | 24.8 a | 152.4 a | 1.4 a | 7.9 a |
| Sept. 8 | 30 | 169.9 b | 170.7 b | 6.0 b | 9.0 b |
| Sept. 29 | 60 | 45.3 c | 74.1 c | 24.5 c | 26.3 c |
| | | | | <i>Old Aster</i> | |
| Aug. 17 | 20 | 4.2 a | 28.5 a | .1 a | .9 a |
| Sept. 8 | 20 | 73.5 b | 70.6 b | 7.8 ab | 1.0 b |
| Sept. 29 | 40 | 36.6 c | 38.3 c | 1.7 b | 3.6 c |

^a Means based on total no. of whole or hatched eggs recovered from a soil sample (450 cm³). Data were transformed to $\sqrt{x+1}$ prior to statistical analysis. Means followed by the same letter within each column for each zone not significantly different (LSD_{.05}).

collected were *Ae. sollicitans*. The majority of these eggs were found on site 7, and 44% of the eggs collected were *Ae. sollicitans*. On site 4 and site 5, an increase in the percentage of *Ae. sollicitans* eggs did not occur in September, but the percentage of soil samples containing eggs of this species did increase from a previous maximum of 23% to greater than 36%. On site 7, September 29, 46% of the soil samples contained *Ae. sollicitans* eggs.

The apparent increase in the proportion and distribution of *Ae. sollicitans* eggs late in September coincided with cooler fall temperatures and an increased nectar supply due to the profuse September blooming of *Aster subulatus*. Differences in temperature tolerances between the 2 species apparently exist. *Ae. sollicitans* can survive cooler more northern climates than can *Ae. taeniorhynchus* (Knight 1967). Eggs and larvae of *Ae. sollicitans* develop at lower temperatures than those of *Ae. taeniorhynchus* (Linley and Evans 1971, Woodard et al. 1968). A relationship exists between nectar availability and the number of eggs per batch that a female *Ae. taeniorhynchus* is capable of laying (Nayar and Sauerma 1975). Thus, increased nectar availability in conjunction with cooler temperature may have created conditions favorable for *Ae. sollici-*

tans population growth late in the season, but we do not have data to substantiate such a hypothesis.

The possibility that heavy rains transport eggs from their original site of oviposition was considered. During this study, 5 sampling dates, May 7, June 15, July 21, August 17, and September 29 were preceded by at least 1 week of dry weather. Seven sampling dates, April 9, May 24, June 8, June 22, July 3, August 3, and September 8 were preceded by heavy rains. The distribution of eggs within the 4 major habitats was not different between the 2 groups of sampling dates. This suggests that the majority of eggs remain in the habitat in which they are laid, despite heavy rains. Also, the presence of hatched eggs on vertical crack walls suggests that eggs generally remain at their site of deposition for considerable lengths of time.

The densities of *Ae. taeniorhynchus* eggs over the season was related to fluctuations in rainfall and standing water levels. For example, on site No. 4 (Fig. 5) each major wet period during the summer greatly reduced the number of eggs remaining on the soil. Egg abundance on site 8 showed a similar, but less pronounced relationship because of prolonged high standing water levels. Overall egg abun-

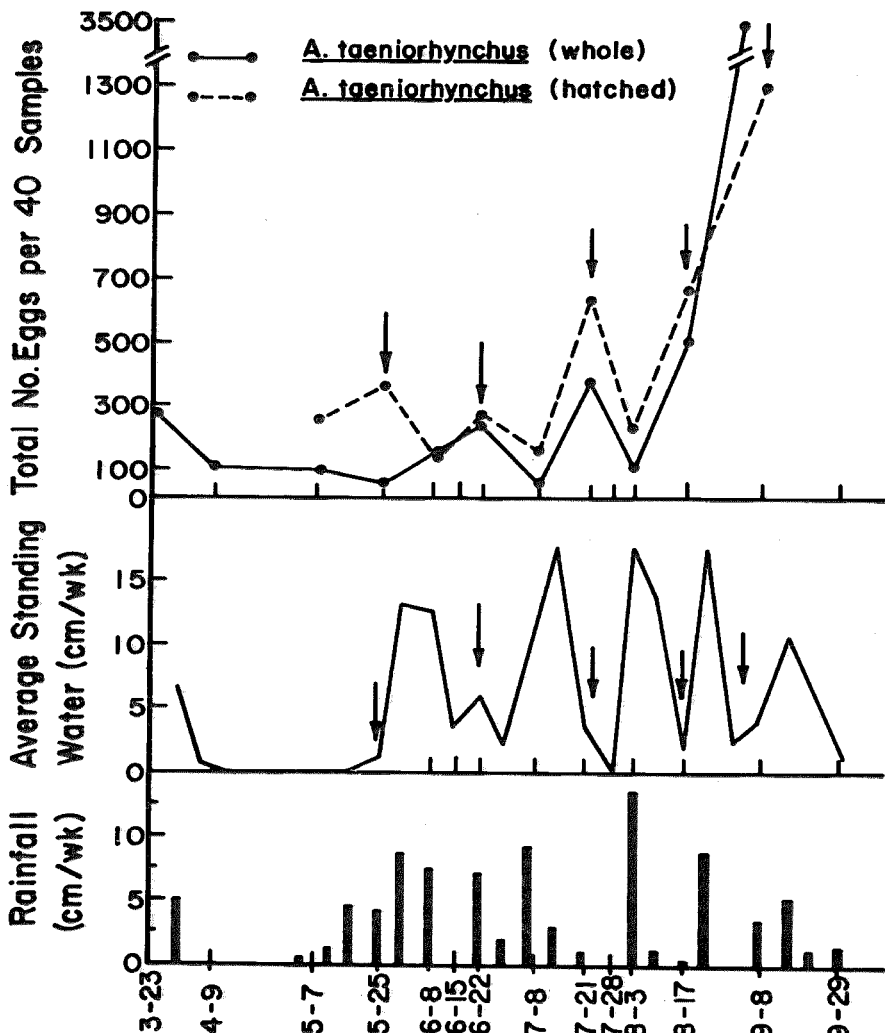


Fig. 5. Total no. of eggs (whole or hatched) of *Aedes taeniorhynchus* recovered from 40 soil samples per sampling date on dredge spoil site No. 4 and corresponding rainfall and standing water depth. March 23–September 8, 1976. Arrows indicate corresponding egg population peaks and water level depressions.

dance on site 8 was much lower than that found on site 4. On site 4, there were 5 peaks in egg density during the sampling period. Each peak followed a period of rain and high level of standing water. A dramatic increase in egg density became apparent in September. Since the numbers of *A. sollicitans* eggs were low throughout most of the season, similar comparison to rainfall and water level is not justified for that species.

SUMMARY AND CONCLUSIONS

Eggs of *Ae. taeniorhynchus* constituted the majority of mosquito eggs found on 3-year-old dredge spoil sites in Onslow County, North Carolina. Eggs of *Ae. sollicitans* comprised approximately 10% of the total egg population from March to September and 26% in late September. This increase coincided with cooler temperatures and increased nectar supply from *Aster subulatus*. The only other eggs found were *Ae. atlanticus* and *Ps. ciliata*.

The distribution of eggs of *Ae. taeniorhynchus* and *Ae. sollicitans* varied from site to site. Habitat preferences were similar on 3 sites and distinctly different on the 4th. Overall, the order (least to most) of habitats based on egg densities on all sites was: bare mud, shrub, old *Aster*, and new *Aster*.

Within the new *Aster* and old *Aster* zones, 5 microhabitats (surface root mats, bare crack walls, algae-lined crack walls of the new *Aster* zone; soil surface and crack walls of the old *Aster* zone) were studied. In the new *Aster* zone, surface root mats supported the densest egg populations. This was followed by bare soil crack walls. In the old *Aster* zone, both crack walls and soil surfaces were important as ovipositional sites. However, neither was as important as the new *Aster* surface root mats. When algae were present on the crack walls in the new *Aster* zone, oviposition was apparently deterred.

Egg density throughout the season was inversely related to rainfall and standing water level. An increase in egg density

was observed as the season progressed, with a marked increase occurring in September, shortly after the blooming of *Aster subulatus*. A gradual decrease in temperature also occurred at this time.

Some eggs were found in soil cracks, but eggs were much more numerous in surface root mats. The presence of cracks is probably more significant in extending larval survival than in affording ovipositional substrate. When eggs were found in soil cracks, the majority were in the top 10 cm.

Since abundance and distribution show extreme variability among spoil sites, it is risky to extrapolate information from one site to another. Each site should be sampled to determine its egg distribution. Mosquito eggs were abundant on all the 3-year-old sites sampled, but very few eggs were found on the 3-month-old sites. This indicates that the age of sites can be an important factor in the density of mosquito eggs.

ACKNOWLEDGMENTS

Appreciation is expressed to Dr. A. M. Witherspoon (Department of Botany, NCSU) for identification of algal samples, to Dr. L. A. Nelson (Department of Statistics, NCSU) for assistance in statistical analysis and to T. D. Edwards for assistance in the sampling.

References Cited

- Bartlett, M. S. 1947. The use of transformations. *Biometrics* 3:39-52.
- Craig, G. B., Jr. and W. R. Horsfall. 1960. Eggs of floodwater mosquitoes. VII. Species of *Aedes* common in the Southeastern United States (Diptera: Culicidae). *Ann. Entomol. Soc. Amer.* 53:11-18.
- Horsfall, W. R. 1956. A method for making a survey of floodwater mosquitoes. *Mosquito News* 16:66-71.
- Horsfall, W. R. and C. G. Craig, Jr. 1956. Eggs of floodwater mosquitoes. IV. Species of *Aedes* common in Illinois. *Ann. Entomol. Soc. Amer.* 49:368-374.

- Horsfall, W. R., R. C. Mills and J. T. Sokatch. 1952. Eggs of floodwater mosquitoes. I. Species of *Psorophora* (Diptera: Culicidae). Ann. Entomol. Soc. Amer. 45:618-624.
- Horsfall, W. R., F. R. Voorhes and E. W. Cupp. 1970. Eggs of floodwater mosquitoes. XIII. Chorionic sculpturing. Ann. Entomol. Soc. Amer. 63:1709-1716.
- Knight, K. L. 1967. Distribution of *Aedes sollicitans* (Walker) and *Aedes taeniorhynchus* (Wiedemann) within the United States (Diptera: Culicidae). J. Ga. Entomol. Soc. 2:7-12.
- Linley, J. R. and D. G. Evans. 1971. Behavior of *Aedes taeniorhynchus* larvae in a temperature gradient. Entomol. Exp. Appl. 14:319-332.
- Matsuo, Kakuo, Y. Yoshida and J. C. Lien. 1974. Scanning electron microscopy of mosquitoes. II. The egg surface structure of 13 species of *Aedes* from Tiawan. J. Med. Entomol. 11:179-188.
- Murphy, W. L. and T. W. Ziegler. 1974. Practices and problems in the confinement of dredged material in Corps of Engineers projects. U.S. Army Engineers Waterways Experiment Station. Dredged Material Research Program. Tech. Rept. D-74-2. Vicksburg, Virginia. 136p.
- Nayar, J. K. and D. M. Sauerman, Jr. 1975. The effects of nutrition on survival and fecundity in Florida mosquitoes. Part 3. Utilization of blood and sugar for fecundity. J. Med. Entomol. 12:220-225.
- Olson, J. K. and S. M. Meola. 1976. Variations in chorionic sculpturing of eggs of *Aedes sollicitans* (Walker). Ann. Entomol. Soc. Amer. 69:96-100.
- O'Meara, G. F. 1976. Salt marsh mosquitoes (Diptera: Culicidae), pp. 303-333. In Cheng, L. (ed.), Marine Insects. American Elsevier Publishing Co., New York, N.Y. 581p.
- Salt, G. and F. S. Hollick. 1944. Studies of wireworm populations. I. A census of wireworms in a pasture. Ann. Appl. Biol. 31:52-58.
- Service, M. W. 1968. A method for extracting eggs from soil samples taken from oviposition sites. Ann. Trop. Med. Parasitol. 62:478-480.
- Woodard, D. B., H. C. Chapman and J. J. Petersen. 1968. Laboratory studies on the seasonal hatchability of egg batches of *Aedes sollicitans*, *Aedes taeniorhynchus* and *Psorophora cingifinis*. Mosquito News 28:143-146.

BLOOD MEAL SIZE OF THE STABLE FLY, *STOMOXYLS CALCITRANS*, MEASURED BY THE HiCN METHOD

T. D. SCHOWALTER AND M. J. KLOWDEN

Department of Entomology, University of Georgia, Athens, GA 30602

ABSTRACT. A chemical method for measuring the blood meal size of *Stomoxys calcitrans* was compared to gravimetric measurement. Results indicated that the hemoglobin-cyanide (HiCN) method gives reliable esti-

mates of blood meal size and may be used under field conditions. This technique was used to measure blood meal sizes of 11.2 μ l for males and 15.1 μ l for females.

INTRODUCTION

Stable flies associated with livestock can cause severe injury, reduced milk production, and increased susceptibility of the weakened animals to death and disease (Bishopp 1913, Bruce and Decker 1958, Campbell et al. 1977). The economic los-

ses attributed to stable flies on livestock have not been correlated with fly feeding activity, however. This is due largely to limitations of conventional techniques for measuring blood meal size in the field.

The commonly used gravimetric method is impractical under field conditions because the prefeeding weight of