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VALIDITY OF LARVAL SURVEYS TO ESTIMATE TRENDS OF ADULT POPULATIONS OF *ANOPHELES ALBIMANUS*

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ABSTRACT. Larvae of *Anopheles albimanus* Wiedemann were collected from representative breeding sites from July 18, 1976, to March 25, 1978 in conjunction with a sterile insect release program on the Pacific coast of El Salvador, Central America. The number of larvae collected per 100 dips from breeding sites was compared with the number of adults captured per man-hour at specified cattle stables throughout the area during the same period. It was found that the larval surveys were not an accurate indicator of the actual population during the rainy season. The study shows a need for a more reliable system of sampling *An. albimanus* larvae in wet season flooded areas if larval collections are used to show relative abundance of that species.

INTRODUCTION

The sterile insect technique (SIT) has shown various degrees of success since it was first proposed by Knipling (1955). Some insects have been successfully controlled or eradicated from certain geographical areas using SIT, while other control efforts have been unsuccessful. One successful program reported by Lofgren et al. (1974) virtually eliminated a population of *Anopheles albimanus* Wiedemann from the area around Lake Apastepeque in El Salvador, Central America. An important reason for the success of that project was the fact that the test site chosen was ideal for the use of a SIT (Breeland et al. 1974). It consisted of a volcanic lake and a nearby rainy-season lagoon, both of which were isolated from other *An. albimanus* breeding by several kilometers. The lake supported larval populations only in a narrow band of vegetation around the periphery. Because the total breeding area was well defined, it was possible to place released sterile males in close proximity to the known location of emerging females for an optimum mating potential.

As a result of the success of the Lake Apastepeque project, a larger SIT program against *An. albimanus* was conducted on the Pacific coast of El Salvador. Much has been published previously about the natural populations of *An. albimanus* and techniques for measuring those populations in the same general area of the present project. Breeland (1972a, 1972b) described several methods of sampling adult *An. albimanus* populations; however, all sampling techniques are influenced by the proximity of the sampling site to existing breeding habitats during specific times of the year. Hobbs (1973a) and Breeland (1974) showed seasonal fluctuations of larval and adult populations of *An. albimanus* in the present study area, and they both concluded that the season (dry or rainy) had a definite effect on the density and distribution of the populations of that species. Furthermore, Hobbs (1973b) showed that insecticidal activities directed against cotton pests in this area substantially affected the indigenous mosquito populations during the latter part of the wet season. Thus seasonal changes are important, and there is a continual need to alter the placement of released sterile males to put them in close proximity to emerging females.

Early in the present program plans were made to conduct routine surveys of the larval population in locations with permanent water and to supplement this activity with surveillance of temporary breeding sites as they became available. It was thought that by monitoring these potential breeding sites within the test area we would be better able to locate release points for the sterile males. We report here the results of surveys made from July 18, 1976 to March 25, 1978, and examine the validity of larval surveys as an indicator of the distribution and density of natural populations.

MATERIALS AND METHODS

Test Site. The study area consisted of approximately 100 km^2 located on the Pacific coast of El Salvador, east of the city of La Libertad. A mountain range on the north side converges with the Pacific Ocean at La Libertad to form a narrow triangular-shaped area about 20 km long, with the apex of the triangle on the west, and widening to about 10 km on the eastern side. The area is basically agricultural, devoted to cotton, sugarcane and pastureland. Larval habitats in the area are greatly diversified and change with the seasons (Breeland 1974). El Salvador has two basic seasons: a wet season, usually from early April until late October or early November with almost daily rains, and a dry season the remainder of the year.

The triangular area is transected by several rivers flowing from the mountains on the north into large estuaries along the Pacific coast on the south. During the rainy season these rivers are characterized by strong turbulent water currents flowing down from the mountains. Some rivers become completely dry during the dry season, while others flow throughout the year, even though the flow is greatly diminished. This reduced flow causes extensive isolated pools of water to form along many of the rivers, and these provide suitable larval habitats for *An. albimanus*. Also, with the reduced river flow, the estuaries are closed to the sea by sand deposits along the beach, so water backs up in the estuaries and floods the surrounding low areas. There are also many marshy areas that contain water year-round, and others that are flooded during the rainy season but are completely dry during most of the dry season. Also, there is some irrigation (both flood and overhead sprinkler types) of pastureland in the area during the dry season providing additional water for breeding sites. Thus, from the standpoint of favorable *An. albimanus* habitat, the area is in a seasonal state of flux.

LARVAL SAMPLING. Designated breeding sites were sampled weekly throughout the test period. Sites were chosen on the basis of the presence of water throughout the year and their capability of supporting *An. albimanus* breeding during at least a part of the year (determined through prior sampling during the 1st year of the SIT project). There were 18 specific sites sampled throughout the study area, including 7 from rivers, 3 from marshes, 4 from drainage or irrigation ditches and 4 from estuaries. All the sites contained water, at least in isolated pools, throughout the year.

Forty samples (dips which collect larvae from an estimated 750 cm^2 of surface area) were taken weekly at each breeding site with a standard 350 ml dipper. All anopheline larvae collected were counted and the number per dip recorded. The 3rd and 4th instars were taken to the laboratory, and species determined. The number of these later instars was calculated per 100 dips, and those numbers were averaged for each type of habitat, and also, collectively for all sites within the area at 4-wk intervals throughout the study.

ADULT SAMPLING. Several stables are located in the study area, and the cattle are brought in from fields at night and placed in the stables or in pens adjacent to the stables. The cattle are excellent hosts for adult female *An. albimanus* seeking a blood meal. After feeding, many of the mosquitoes seek shelter in the rafters and other protected areas of the stables where they rest the remainder of the night and much of the following day (Breeland 1972b, Lowe and Bailey 1979). Fourteen stables were selected for this study on the basis of their suitability as collection sites for *An. albimanus* adults demonstrated during the 1st year of the SIT study. They were widely spaced throughout the entire study area, providing an excellent representative sampling of the adult population. By using mouth aspirators, adult anophelines were captured from each site at weekly intervals, transferred to holding cages, taken to the laboratory and identified as to species, and the numbers recorded. The numbers in each collection represented 1 man-hr of collection time made in the evening after complete darkness. As with the larval data, the numbers were averaged at 4-wk intervals during the study.

RESULTS AND DISCUSSION

All of the data for both the larval and adult surveys for the entire study area were summarized in order to report a representative picture of the total population trends. Figure 1 shows the seasonal variation of larval density of *An. albimanus* from the 4 types of breeding habitat (rivers, marshes, drainage and irrigation ditches, and estuaries) that were prevalent in the study area.

During the 2 dry seasons shown, the larval densities in all 4 types of habitat appeared to be many times higher than during the 2 wet seasons. However, there was no apparent pattern observed during the 2 consecutive dry seasons in relation to the habitat where the most larvae were produced or where breeding began first. For example, in the dry season of 1976–77 larval density from all 4 habitat types began to increase at approximately the same time, but the density in marsh habitats peaked at a level of almost twice that for the other habitats. In the dry season of 1977–78, density in marsh habitats increased slowly throughout the dry season and never reached the numbers present in rivers or in drainage and irrigation ditches. Also, as is plain in Fig. 1, the larval density in all but the marsh habitat peaked about 4–8 wk earlier than in the previous dry season. Even though the densities were somewhat variable during the dry seasons, it is obvious from Fig. 1 that our larval sampling techniques indicated the presence of relatively large numbers of larvae during the dry season. It is also obvious that those same sampling techniques indicated a near absence of larvae during the wet season.

When the average larval density of the 4 combined habitats is plotted against the average adult population for the same period (Fig. 2) we can see a discrepancy. It can be noted from the graph that during both the 1976–77 and 1977–78 dry seasons the larval and adult collection curves were similar. However, during both wet seasons the larval populations appeared to be virtually nonexistent at the 18 sampling sites, while the adult populations sampled in the 14 stables appeared to be relatively high.

Table 1 shows the averages (4-wk intervals) for adult *An. albimanus* captured per man-hr and also for the larvae per 100 dips throughout the area for the entire period. Also the ratios of the number of adults captured to the number of larvae collected $\left(\frac{\text{adults/man-hr}}{\text{larvae/100 dips}}\right)$ are shown. This comparison does not actually measure the difference in the natural larval

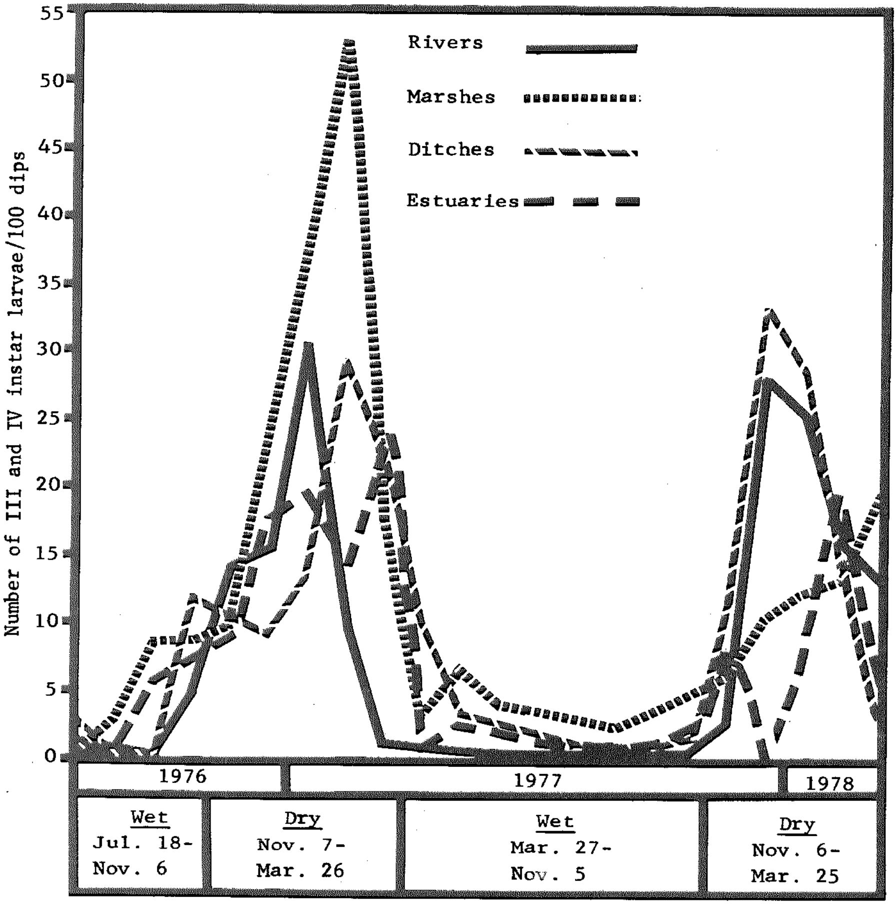

Fig. 1. Seasonal variation in density of *Anopheles albimanus* larvae collected from different types of habitats on the Pacific coast of El Salvador from July 18, 1976, to March 25, 1978.

Table 1. Comparison of larval and adult populations of *Anopheles albimanus* during the wet and dry seasons, July 18, 1976, to March 25, 1978, on the Pacific coast of El Salvador, C.A. (4-week averages).

4-wk Period	Adults captured/man-hr	3rd and 4th instar larvae collected/100 dips	Ratio of adults to larvae (No. adults/man-hr / No. larvae/100 dips)
		Wet season: 1976	
Jul. 18–Aug. 14	43.5	1.2	36.3
Aug. 15–Sep. 11	40.7	0.8	50.9
Sep. 12–Oct. 9	42.1	3.1	13.6
Oct. 10–Nov. 6	23.7	7.7	3.1
		Dry season: 1976–77	
Nov. 7–Dec. 4	21.1	11.5	1.8
Dec. 5–Jan. 1	33.8	15.4	2.2
Jan. 2–Jan. 29	60.2	23.9	2.5
Jan. 30–Feb. 26	60.1	22.4	2.7
Feb. 27–Mar. 26	19.0	14.4	1.3
		Wet season: 1977	
Mar. 27–Apr. 23	11.6	4.0	2.9
Apr. 24–May 21	13.8	3.1	4.5
May 22–Jun. 18	28.6	2.1	13.6
Jun. 19–Jul. 16	30.0	1.6	18.8
Jul. 17–Aug. 13	18.5	0.7	26.4
Aug. 14–Sep. 10	28.8	0.4	72.0
Sep. 11–Oct. 8	31.1	1.4	22.0
Oct. 9–Nov. 5	8.9	1.6	5.6
		Dry season: 1977–78	
Nov. 6–Dec. 3	12.4	6.4	1.9
Dec. 4–Dec. 31	37.2	20.3	1.8
Jan. 1–Jan. 28	90.9	17.3	5.3
Jan. 29–Feb. 25	65.2	15.6	4.2
Feb. 26–Mar. 25	47.4	10.3	4.6

and adult populations, but it provides a measure of the reliability of the sampling techniques in the different seasons. The humber of adults captured per man-hr (4-wk averages) in the 14 stables during the study ranged from a low of 8.9 to a high of 90.9, a 10.2-fold variation. The humber of larvae per 100 dips collected from the 18 potential breeding sites ranged from 0.4 to 23.9, a 59.8-fold difference.

We consider the adult collections more representative of the actual *An. albimanus* populations because the habit of adults feeding on the cattle in the evening and seeking shelter in the stables does not, to our knowledge, change appreciably with the seasons, whereas the breeding sites change drastically from the wet to the dry seasons. The ratio of adults to larvae (Table 1) shows the variation of larval and adult populations with the seasons. If the 2 systems of sampling were compatible, the ratio of adults to larvae should show a minimum variation throughout the year, or when data were plotted they would follow similar curves as they did during the 2 dry seasons (Fig. 2). The data in Table 1 also show little variation in the ratio between the adult and larval samples during the dry seasons with a high ratio of 2.7 in 1976–77 and 5.3 in 1977–78. However, in the wet seasons, the ratios were as high as 50.9 in 1976 and 72.0 in 1977. This implies that although the larval sampling during the wet season indicated a lack of large *An. albimanus* populations, the number of adults captured in stables indicated that relatively large populations were present. Thus, the larval surveys of *An. albimanus* did not provide an indication of the density of the adult population on the Pacific coast of El Salvador.

One possible explanation for the discrepancy could be the impact on mosquitoes of agricultural spraying conducted against cotton pests. This appears to be significant between August and November (Hobbs 1973b), but does not explain the high ratios of adults to larvae observed in May, June and July. Another possible explanation should be investigated. During the dry season, larval breeding is restricted to definable areas in the rivers, marshes, drainage and irrigation ditches, and estuaries, and breeding outside those areas is minimal. With the onset of the rainy season the rivers, marshes, ditches, and estuaries are flushed with heavy rains almost daily, reducing their capability of supporting larval populations. However, vast areas that contain no water in the dry season become covered with flood waters, and many of those areas become ideal larval

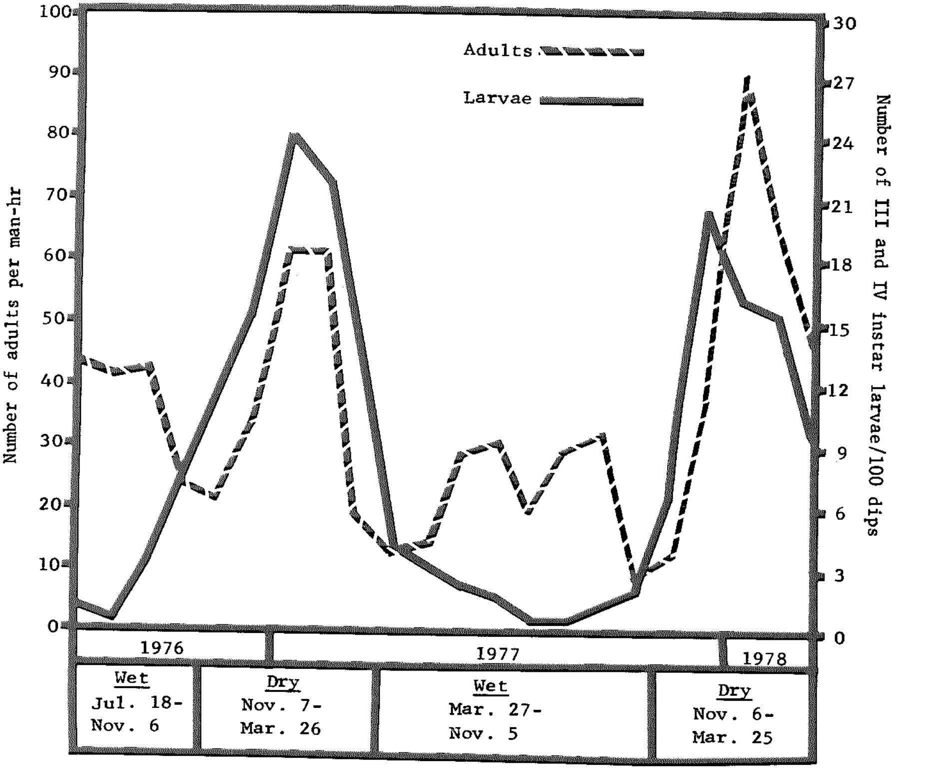

Fig. 2. Comparison of densities of adult and larval *Anopheles albimanus* on the Pacific coast of El Salvador from July 18, 1976, to March 25, 1978.

habitats. As a result, the larval population is spread out over a much larger area than is normal for the dry season. With this spread of potential breeding sites, the number of larvae sampled per 100 dips at the standard sites becomes reduced because of dilution due to the flushing of larvae into larger areas, and to adult females ovipositing over a larger area. A more reliable estimate of the natural population trends of *An. albimanus* on the Pacific coast of El Salvador is therefore provided by the capture of adults, rather than by larval sampling, at least during the rainy season. Consequently, unless a reliable system of population estimation by larval sampling in wet season flooded areas is developed, larval sampling will have limited value and must be supplemented with other methods for determining the placement of released sterile males in a SIT program.

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