VARIATIONS IN THE EGG HORIZONS OF *PSOROPHORA COLUMBIAE*[1] ON LEVEES IN TEXAS RICELANDS[2]

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ABSTRACT. There is a great deal of variation in the location and dimensions of *Psorophora columbiae* (Dyar and Knab) egg horizons on riceland levees in Texas. This variation appears to be the result of differences in soil moisture content at given points on levee slopes at different times of the year as influenced by irrigation water and rainfall. Data presented herein indicate that virtually any point along a levee slope is subject to having eggs deposited on it provided the soil moisture conditions preferred by *Ps. columbiae* females are satisfied. The presence of irrigation water and/or heavy rainfall results in eggs being deposited at the higher elevations on the levees and in greatest numbers at locations on the levees that are 0–4 in. (10 cm) in vertical elevation above the surface of standing water when it is present in a field. At times when there is no irrigation water or when there is little or no rainfall, the zones of maximum egg deposition for *Ps. columbiae* tend to be at the lower elevations on levees. For example, the zone of maximum egg deposition on levees in the field used in this study was 0–6 in. (0–15 cm) in elevation above the bottoms of the levees during the year that the field was used as a pasture and not subject to irrigation.

INTRODUCTION

Levees in fields planted in rice as well as ones in fields maintained in a fallow state represent an important source of oviposition sites for populations of *Psorophora columbiae* (Dyar and Knab) in the Texas riceland agroecosystem (Meek and Olson 1976). However, the specific location and distribution of the eggs deposited on the slopes of these levees is not well documented.

Moisture content of the soil is one of the major factors in determining where *Ps. columbiae* females will deposit their eggs on a levee at a given point in time (Olson and Meek 1977); and according to Horsfall (1963), soil moisture content also plays a significant role in determining the number of eggs that will be deposited at a given location over an extended period of time. The end result is that egg populations of *Ps. columbiae,* like those of other floodwater mosquito species, tend to occur in characteristic zones or horizons on levees (Horsfall 1963). The purpose of the study described herein was to gain a quantitative insight as to the variation in the location and dimensions of *Ps. columbiae* egg horizons on levee slopes in Texas ricelands as influenced by natural and man-induced variations in soil moisture content.

METHODS AND MATERIALS

The study site used in this investigation was a field located on the J. T. Garrett Ranch near Danbury, Brazoria County, Texas. The study period lasted for approximately a year and a half (May, 1973 through September, 1974) with the study field being planted in rice during the first 5 months (May–September, 1973) and used as a pasture for cattle during the remaining 12 months (September, 1973–September, 1974).

The relative size and location of *Ps. columbiae* egg populations occurring on the levee slopes in the study field were determined using a modification of the soil sampling techniques described by

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[1] Diptera:Culicidae. *Psorophora columbiae* (Dyar and Knab) = *Ps. confinnis* (Lynch-Arribálzaga) in part. See Belkin et al. 1970.

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Horsfall (1956) and by Meek and Olson (1976). Beginning May, 1973 (just prior to the first flush of irrigation water into the field after it had been planted in rice), soil samples were periodically taken from several levee sites established over the expanse of the study field. These designated sites were located within each of 3 pans (i.e. upper, middle, and lower portions of the field). A total of 8 sites/sampling date was used during 1973 and early 1974, and 6 of these were sampled from May–September 1974. The levee soil samples consisted of 6 × 6 × 1 in. (15 × 15 × 2.5 cm) blocks of soil cut sequentially with the aid of a sharpened mortar trowel from a 6 in. (15 cm) wide strip of soil extending from the top to the bottom of a given levee slope. The relative position of each sample, in terms of its elevations above the bottom of the levee ditch (in inches), was determined using the equipment shown in Figure 1. The elevation of each soil sample was calculated by measuring the vertical distance from the center of the given block of soil to a leveled string (Fig. 1B) which ran from the top of the levee to a stake (Fig. 1E) embedded in the center of the levee ditch. The vertical distance of the given soil sample was then subtracted from the vertical distance between the levee ditch bottom and the leveled string. Following the elevation determination, each soil sample was individually removed from the levee soil strip, placed into a plastic bag and labelled as to date, levee site, and elevation.

All soil samples were transported to the laboratory at College Station, Texas, where they were subjected to a soil washing and salt flotation process (Horsfall 1956). Eggs retrieved from the samples were counted and identified using taxonomic keys by Horsfall et al. (1952) and Ross and Horsfall (1965).

During the course of the study, records were kept on the irrigation schedule for the period of time that the field was in rice. Records were also kept on the level of standing water located on the levee slopes at the times when soil samples were taken. The standing water in the field resulted from irrigation activities or, in the case of the second year when the field was a pasture, the occurrence of heavy

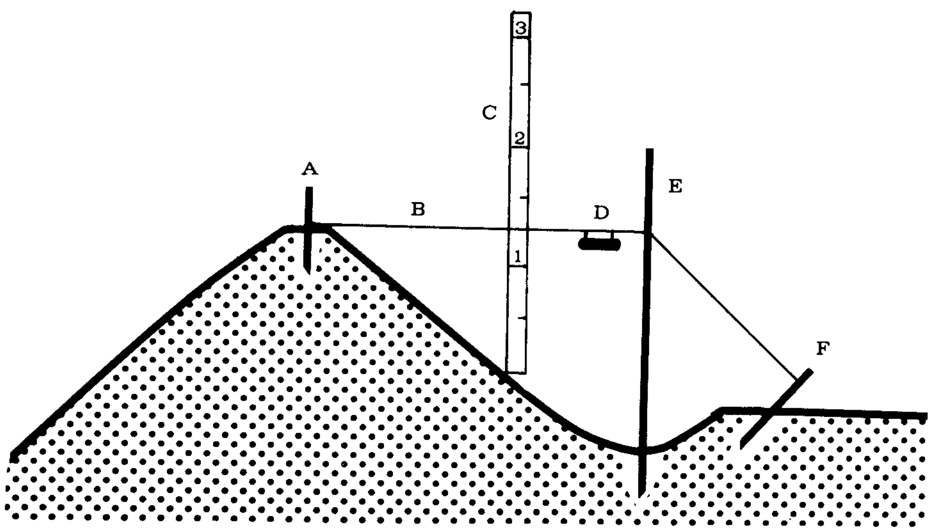


Fig. 1. Equipment used to determine soil sample elevation on levee slopes; (A) 5 in. wooden stake; (B) string; (C) yard stick; (D) bubble-type level; (E) 3 ft. stake and (F) metal stake.

rains. Whenever soil samples were taken following drainage of the field, all previous water levels that had remained relatively stable were measured according to the height of the water marks on the levee slopes. These water marks were detectable most of the time by finding horizontal escarpment lines along the levee slopes. Climatic conditions, such as temperature, rainfall, wind speed and wind direction, were continuously monitored throughout the active mosquito seasons of 1973 and 1974.

The relative size of *Ps. columbiae* female populations occurring in the vicinity of the study field was also monitored periodically throughout the active mosquito seasons of 1973 and 1974 using CDC miniature light traps baited with dry ice (Newhouse et al. 1966). Mosquitoes collected in these traps were counted in accordance with trapping date and confirmed as to species using taxonomic keys by Carpenter and LaCasse (1955).

RESULTS

Data reflecting the distribution of *Ps. columbiae* eggs over the levee slopes of the study field during 1973 and 1974 are summarized in Figure 2. Each component of this figure (A–J) depicts a composite drawing of a cross-section of a levee slope drawn to scale based on the average number of 6 × 6 × 1 in. (15 × 15 × 2.5 cm) samples taken in the study field at a given elevation on a particular sampling day. Vertical lines along the cross-section indicate 2 in. (5 cm) increases in elevation. Figures 2A–F represent the average

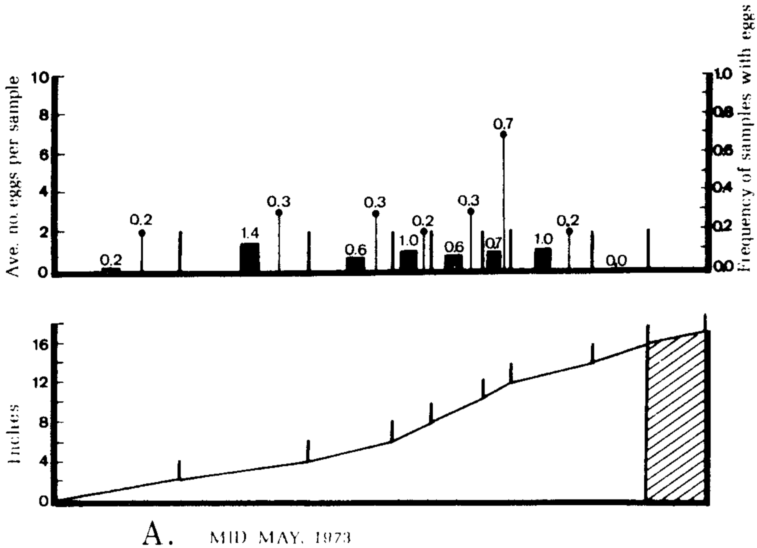
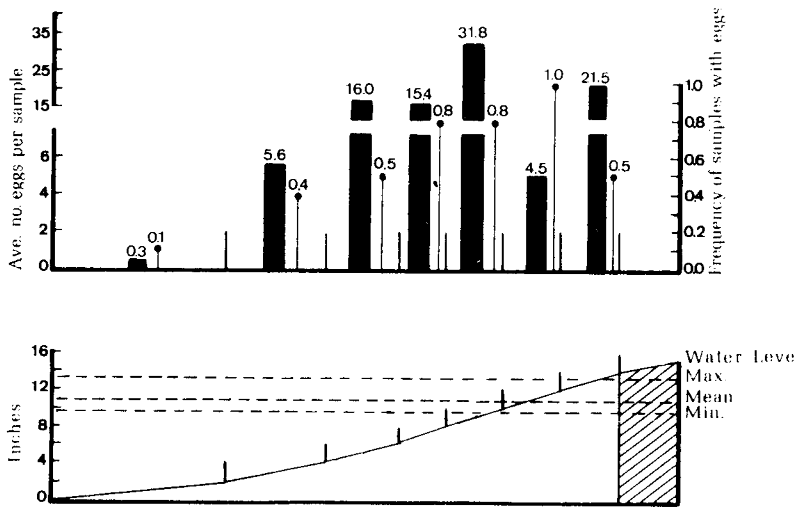
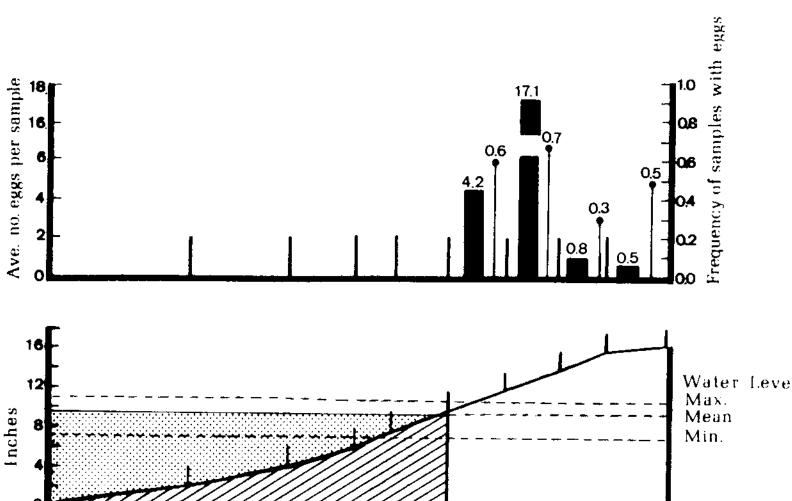


Fig. 2. Distribution and frequency of *Psorophora columbiae* eggs on riceland levee slopes.

number of eggs collected at each elevation per 8 levee slopes for each sampling date during 1973 and early 1974. For the remainder of 1974, six of these levees were continuously sampled for each of the sampling dates (Fig. 2G–J). The graph above the levee cross-section shows the average number and frequency of eggs occurring in samples taken at a given elevation along the levee slope on a particular sampling date. To further assist in the interpretation of the data, dotted lines are superimposed over each levee profile to represent stabilized water levels on the

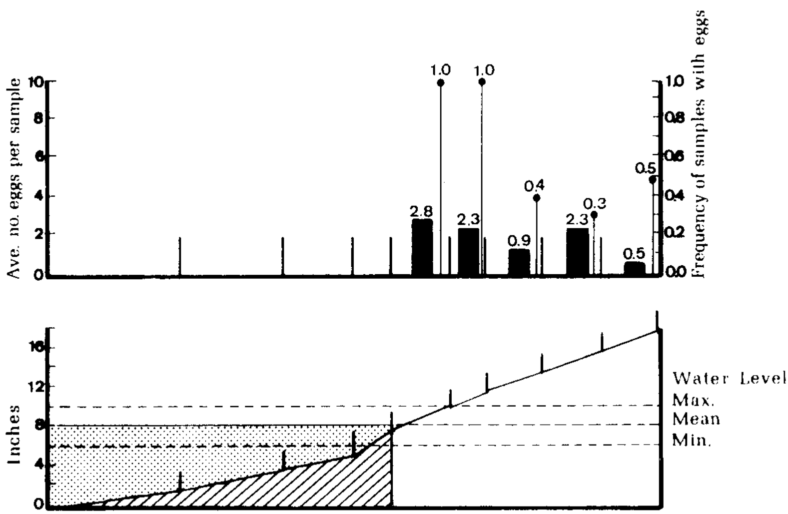


B. JUNE, 1973

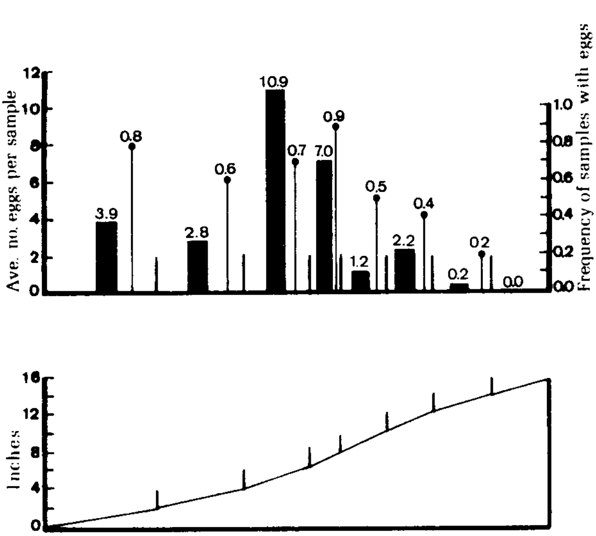


C. MID JULY, 1973

levee slopes. The shaded portions of Figs. 2C, D, F, and G represent the average depth of standing water present on the sampling date. During the soil sampling period, when the active rice field was drained (Fig. 2B), only dotted lines are superimposed over the levee profile to indicate previous water levels as denoted by escarpment areas on the levee slopes. No dotted lines are provided for Fig. 2E, H, I, and J due to the lack of standing water and the absence of fresh escarpment lines on the levee slopes. Table 1 summarizes the status of irrigation activi-



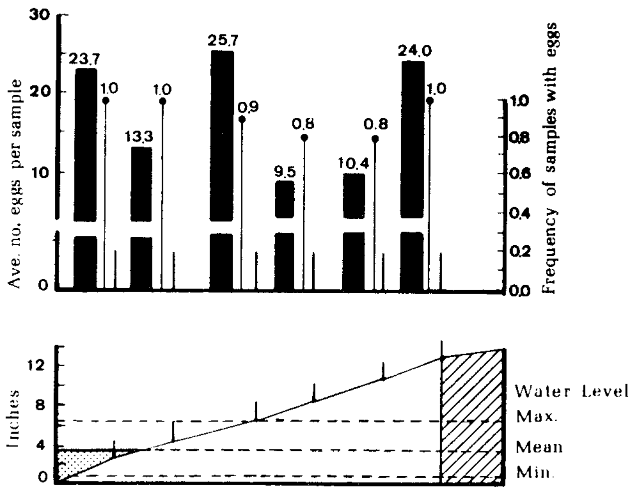
D. LATE AUGUST, 1973



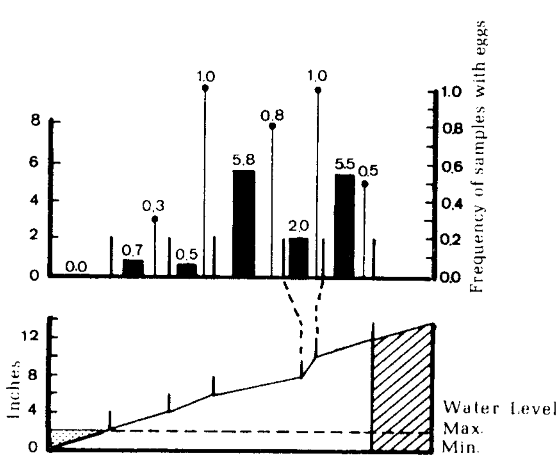
E. SEPTEMBER, 1973

ties and the accumulation of precipitation relative to when levee soil samples were taken. Figure 3 reflects the relative sizes of female *Ps. columbiae* populations that were most likely responsible for the deposition of eggs in riceland fields during the study period.

At the outset of the study (May, 1973), both adult female (Fig. 3A) and egg populations of *Ps. columbiae* (Fig. 2A) in the study field were relatively low (100–200 females/trap and a 0–1 egg/sample, respectively). The eggs were rather evenly distributed over the expanse of the levee slopes and had been disturbed during the course of preparing the field for planting. The soil moisture content at this time was due entirely to natural precipitation since the field had not been subjected to irrigation at the time that the initial soil samples were taken (Table 1). There was a substantial increase in both

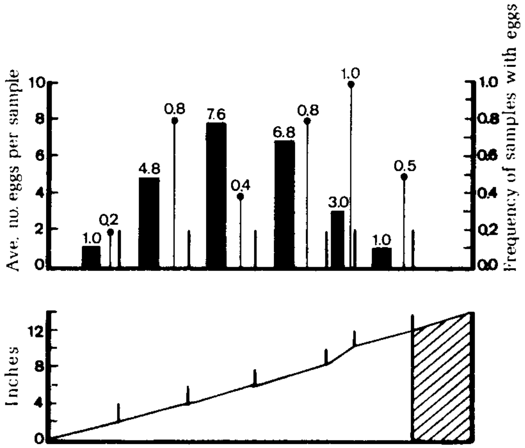


F. EARLY FEBRUARY, 1974

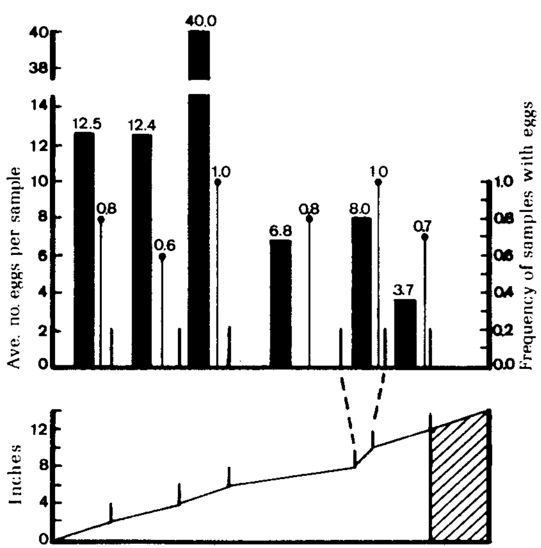


G. MID MAY, 1974

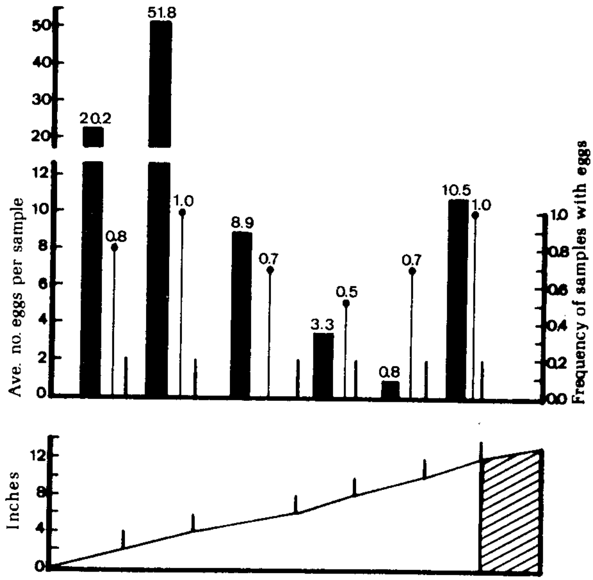
the number of female *Ps. columbiae* in the vicinity of the study field (Fig. 3A) and eggs present in levee slope soil samples taken from the field on 1 June 1973 (Fig. 2B). The field was being temporarily irrigated for the third time when the June soil samples were taken (Table 1). The water level on the levees when irrigation water was in the field during the May flushes ranged between 9.5–13.5 inches in height and eggs tended to occur more frequently and in higher average num-



H. MID JUNE, 1974



I. EARLY JULY, 1974



J. LATE SEPTEMBER, 1974

Table 1. Irrigation activity and precipitation accumulation occurring during the period when soil samples were being taken in a study field to assess the distribution of *Psorophora columbiae* eggs along levee slopes in ricelands near Danbury, Texas, 15 May 1973–5 October 1974.

Date	Irrigation Activity	Accumulated Rainfall (inches) April–Nov 1973	Accumulated Rainfall (inches) April–Oct 1974	Total Levee Soil Samples Taken on A Given Date[1]
15 May 1973	First Flush	12.6	—	71 (1–18)
22 May	Second Flush	12.6	—	—
1 Jun	Third Flush	13.0	—	48 (2–18)
15 Jun	60-day Flood Initiated	26.0	—	—
15 Jul	Flooded	28.6	—	26 (5–8)
23 Aug	Flooded	38.9	—	24 (2–8)
17–18 Sep	Drained/Harvested[2]	51.1	—	—
22 Sep	Pastured	51.1	—	59 (1–15)
15 Nov	Pastured	63.4	—	—
5 Feb 1974	Pastured	—	—	33 (2–10)
17 May	Pastured	—	11.2	21 (1–6)
13 Jun	Pastured	—	12.0	23 (1–5)
4 Jul	Pastured	—	12.9	25 (1–9)
28 Sep	Pastured	—	24.1	27 (1–7)
5 Oct	Pastured	—	28.7	—

[1] Numbers in parentheses indicate the range in number of soil samples taken at a given 2 in. rise in vertical elevation.

[2] The study field was not irrigated after this point in time.

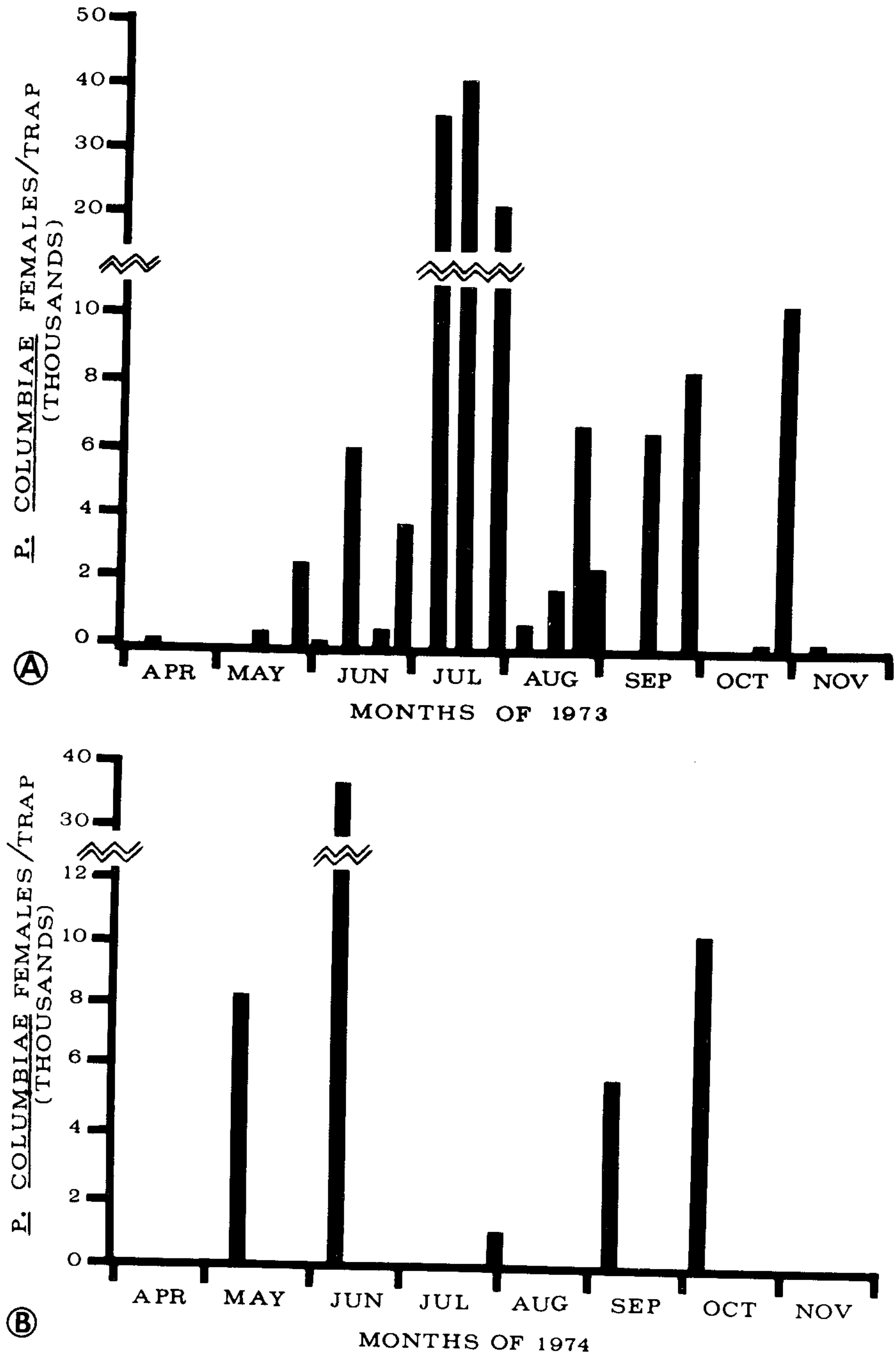


Fig. 3. Average numbers of *Psorophora columbiae* females per trap collected in CDC miniature light traps set at the riceland research site in Brazoria County, Texas during (A) 1973 and (B) 1974.

bers in soil samples taken from the 8–14 in. height zone on the levees following these flushes (Fig. 2B).

By 15 July, 1973, when the third set of levee soil samples was taken, the field had been under a continuous state of flood for approximately 1 month (Table 1) with the water level ranging between 7–11 in. zone of levee height (Fig. 2C). Eggs deposited by the extremely large populations of female *Ps. columbiae* prior to July 15 (Fig. 3A) were most abundant and most frequently found in samples taken from the 10–14 in. zone of levee height (Fig. 2C). The data obtained from soil samples taken on 23 August, 1973, (near the end of the continuous flood period) indicated that the situation was generally the same as that observed in July (Table 1 and Fig. 2D and 2C, respectively).

During 7–18 September, 1973, the study field was drained and harvested, thus exposing the entire surface of the levee slopes to ovipositing mosquitoes for a period of 4–15 days prior to taking the fall soil samples on 22 September (Table 1). Eggs retrieved from these samples tended to occur most frequently and in the greatest numbers in the samples taken below the 8 in. zone of levee height with the greatest numbers of eggs being present in samples from 4 to 8 in zone (Fig. 2E). Subsequent to the September sampling date, the study field was used as a pasture for cattle and was subjected to frequent partial flooding as the result of rainfall that occurred periodically throughout the remainder of the active mosquito season of 1973 (Table 1).

A mid-winter soil sampling effort was made in February 1974 so as to determine the final dimensions of the zone of overwintering egg populations deposited on levee slopes during the fall by *Ps. columbiae* females. As shown in Figure 2F, the average number of eggs per levee soil sample taken in February was high (9.5–25.7 eggs/sample), and the eggs were widely distributed over the expanse of the levee slopes. Standing water was present in the field at the time that the soil samples were taken in February and ranged in depth between 0.5 and 6.0 in. of levee height (Fig. 2F).

By mid-May, 1974, when the 7th set of soil samples had been taken, the levee slopes and the overwintering mosquito egg populations had been subjected to a series of partial spring floods resulting from rainfall occurring in April and early May (Table 1). These floods resulted in the formation of an escarpment zone of soil erosion at the 8–10 in. level of levee height and there were 0–2 in. of water standing in the study field at the time the soil samples were taken on 17 May, 1974 (Fig. 2G). The population of eggs retrieved from these samples were most abundant in the samples taken from the plateaus located immediately above and below the escarpment zone; i.e., at the 6–8 and 10–12 in. zones of levee height (Fig. 2G). The egg populations occurring on the levee slopes in May 1974 were probably a combination of eggs deposited by mosquitoes during the fall of 1973 and by the ones arising as the result of the spring floods in 1974 (Fig. 3B). By 13 June, 1974, when the next soil samples were taken, the spring populations of *Ps. columbiae* females had reached their peak in abundance (Fig. 3B) and approximately another inch of rainfall had been accumulated (Table 1). Eggs were present in at least some of the soil samples taken from each 2 in. increase in levee height during June; but they were most abundant in samples taken from the 2–10 in. zone (Fig. 2H).

Eggs were again present in at least some soil samples taken at each 2 in. increase in levee height on 4 July, 1974 and, again, they were most abundant at points below 10 inches in elevation (Fig. 2I). Approximately one additional inch of rain had fallen between the June and July sampling periods of 1974 (Table 1); but no standing water resulted from these rains.

By 28 September, 1974, when the last set of soil samples were taken in the study, adult populations of *Ps. columbiae* were increasing (Fig. 3B) and probably were the result of the larval hatch that occurred following the floods that took place in the ricelands as an aftermath to heavy rains that fell during August and September (Table 1). Eggs were present in samples taken from each 2 in. increase in elevation on the levees in September. However, the bulk of the eggs and the largest number of eggs per sample generally occurred at elevations below 6 inches in levee height (Fig. 2J).

DISCUSSION

The results described herein indicate that *Ps. columbiae* females have the potential of depositing their eggs at any elevation on levee slopes in Texas ricelands with the end result being a composite egg population that may eventually be distributed over the entire expanse of the levee slope (Fig. 2F). However, the zones vary along the levee slope where maximum egg deposition occurs at given points in time during the active mosquito season. Soil moisture conditions, as influenced by irrigation schedules and rainfall, appear to be among the more important factors contributing to this variation in the location of zones of maximum egg deposition. Results of laboratory studies described by Olson and Meek (1976) support this hypothesis in that *Ps. columbiae* females tended to deposit the bulk of their eggs on soil whose moisture content ranged between 75% to slightly above field capacity as defined by Box and Bennett (1959). When standing water is present, this zone of preferred soil moisture content occurs within the first 4 in. (10 cm) rise in levee height above the water line (Olson and Meek 1977).

During the spring of years when a field is being used for the production of rice, flushes of irrigation water tend to cause the zones of preferred soil moisture content for ovipositing *Ps. columbiae* females to be located at points mid-way to near the top of the levee slope (Fig. 2B). The exact location of the zones of maximum egg deposition during this time will, of course, vary in accordance with the degree of fluctuation in the depth of irrigation water, the abundance of gravid female mosquitoes present at a given point in time, and the length of time that the soil moisture at a given location on the levee remains within the range preferred by ovipositing *Ps. columbiae* females. The latter situation would be influenced by such factors as the stability in the depth of irrigation water due to the occurrence of rainfall and the rate of evaporation and percolation of water in the soil. It is likely that, the longer the soil moisture conditions remain within the preferred range for ovipositing mosquitoes at a given location, the greater the number of eggs that will eventually be deposited at the location over time (Horsfall 1963). The influence of the stability of irrigation water levels on the pattern of levee populations of mosquito eggs was best exemplified by data collected during July 1973 when the study field was being subjected to a continuous flood of irrigation water and there was very little rainfall to otherwise influence soil moisture content on the levees (Fig. 2C and Table 1). At this time, the zone of maximum egg occurrence was located in a band extending from 0–4 in. (10 cm) in height above the surface of the standing irrigation water: the zone determined in our laboratory studies to be optimum for egg deposition by *Ps. columbiae* (Olson and Meek 1977). This trend continued to show itself through August 1973, at least in terms of the frequency at which eggs were found in levee soil samples from the 0 to 4 in. zone above the water level (Fig. 2D). The slight increase in egg numbers above this zone during August, 1973 was probably due to the influence of the increased rainfall that occurred between the July and August, 1973, sampling dates (Table 1).

The removal of irrigation flood water in the fall in preparation for rice harvest correspondingly exposes the entire face of the levees to egg deposition by *Ps. columbiae* females. Egg populations subsequently deposited along the levee slopes tend to expand in their vertical dimensions until the full vertical limits of the levee slope may be encompassed (Fig. 2E, F). Again, it is probably the amount of rainfall that occurs during the fall months and its subsequent influence on soil moisture content that will dictate the number of eggs that will ultimately be occurring at any given point along levee slopes in a harvested rice field. In the case of our study, rains kept the soil moist throughout most of the remaining active mosquito season following the harvest of the study field in 1973 (Table 1).

Once a field is placed into a fallow state or converted into a pasture, rainfall becomes the only source of moisture that will influence the soil moisture content on the levees which are left intact in Texas ricelands. Under such conditions, the soil at the base of the levees tends to remain moist and attractive to ovipositing mosquitoes longer than is the case for soil at higher elevations along the levee slopes. This was indicated in our study by the fact that, as the active mosquito season progressed during 1974, the zone of maximum egg deposition for *Ps. columbiae* receded down the levee slopes in the study field until the bulk of the eggs were located in a zone below 6 in. (15 cm) in levee height (Fig. 2H, I, J).

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