MOSQUITO SPECIES SUCCESSION IN A DAMBO IN AN EAST AFRICAN FOREST[1, 2]

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ABSTRACT. The mosquito larval and pupal fauna of a dambo in a primary forest in Nairobi Area, Kenya was monitored during the short rainy season. The density of the immature stages of 6 species was recorded daily for a 3 month period. *Aedes cumminsii mediopunctatus, Ae. lineatopennis* and *Ae. sudanensis* were the first 3 species collected following flooding. *Culex quasiguiarti, Anopheles coustani* and *Cx. theileri* were collected beginning 15, 17 and 33 days respectively following flooding. Each of the 3 *Aedes* spp. disappeared after one generation. No immature mosquitoes were recovered after day 48.

INTRODUCTION

The mosquito fauna associated with the temporary and infrequent flooding of dambos (vleis) (Ackermann 1936) is being studied in Kenya in areas where Rift Valley fever (RVF) has occurred. Between outbreaks, RVF virus is believed to be maintained (Shope et al. 1982) in forests or secondarily derived grasslands of comparatively high rainfall and humidity. These zones generally lie between the 15°C and 20°C isotherm (ecological zone II, Pratt et al. 1966). During this investigation we studied the mosquito fauna found in a dambo in a forest of the type commonly occurring in ecological zone II.

According to Mackel (1974), dambos are shallow streamless depressions at the headwaters of drainage systems in eastern and southern Africa. They are seasonally waterlogged and grass covered to varying extents, and without a true woodland vegetation. The surrounding woodland or scrub woodland usually stops abruptly at the dambo margin. The existence and form of a dambo is dependent upon relative relief of the surrounding terrain, seasonality of climate, vegetation, soil types and water. They are varied in shape and extend from a few meters to over several kilometers in length and up to several hundred meters in width. Despite their different shapes, dambos show a similar zonation from the margin toward the centers. A typical dambo cross profile is illustrated in Fig. 1. The washbelt slopes downward from the woodland and is characterized by the presence of surface pebbles. The central part is marked by a network of seepage lines forming the seepage zone. Flooding of the seepage zone, producing surface water, may only occur after extended periods of continuous heavy rainfall. Between the washbelt and the seepage zone there is a transitional zone marked by the decreasing size of the surface pebbles and increasing moisture content. The washbelt is composed of discontinuous grassland, and toward the center the vegetation becomes

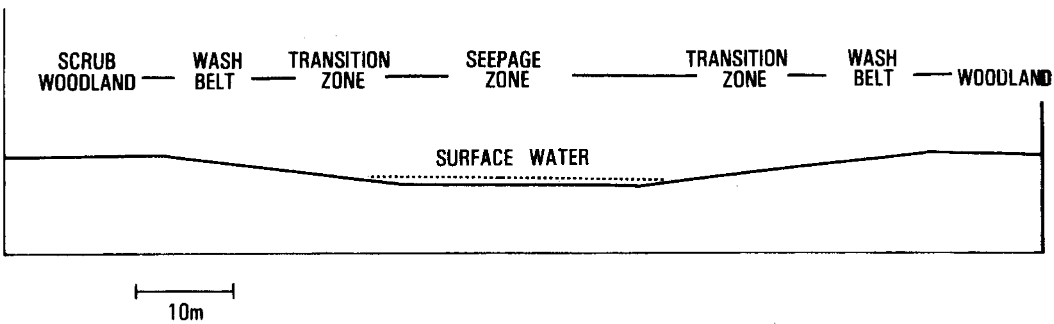

Fig. 1. Cross profile of long axis of the Karura Forest dambo.

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denser with an increasing number of erect rhizomatous herbs. The seepage zone contains both a moderately dense herb and tufted grass cover. Seasonal changes affect the vegetation of the dambos, and by the end of the rainy season the area of bare ground is reduced by the expansion of the vegetation.

Dambos are ideal habitats for mosquito larvae as they exist in geographical areas marked by distinct wet and dry seasons and are subject to seasonal flooding. Our 3 month study describes the daily relative density of immature stages of six species of mosquitoes in a dambo in a primary forest in Nairobi Area, Kenya during the short rainy season (October 1 to December 31, 1982). Emphasis was placed on studying species succession of developmental stages and relative population levels.

MATERIALS AND METHODS

The dambo monitored in this study (Fig. 2) is located at approximately 1° 14′ 30″ S. latitude and 36° 50′ E. longitude in the central part of the Karura Forest, Nairobi Area, Kenya. The Karura Forest is one of several small relict forest stands distributed along the foothills of the eastern edge of the Kikuyu Escarpment, between Nairobi and Thika, at an elevation of 1700 m. The dambo, situated in a forest clearing, is roughly elliptical in shape, measuring approximately 50 × 70 m. The dambo exhibits the typical zonal differentiation common to most dambos (Fig. 1). Prior to the rainy season (October 1, 1982), the washbelt varied from 15–20 m wide with approximately 50% of its area remaining bare of vegetation; the transitional zone varied from 5–10 wide and was approximately 10–20% bare ground. After the rainy season (December 31, 1982), bare ground represented only approximately 35% of the washbelt and 5% of the transitional zone. The seepage zone, about 20 m in diameter, was 5% bare prior to the rains and 1% after the rains. When the seepage zone became flooded, approximately 75% of the surface area of the standing water had extensive emergent vegetation. The emergent vegetation in the central area was primarily the rhizomatous herbs *Typha domingensis* (Persoon) and *Typha latifolia* (Linnaeus) while in the marginal areas along the transitional zone the short tufted grass *Eragrostis exasperata* (Peter) predominated. The entire surface of the dambo remained in direct sunlight for approximately 10 hours each day and the temperature of the water, as measured at 1100 hr each morning varied between 18°–30°C.

Fig. 2. The Karura Forest dambo, Nairobi Area, Kenya on November 10, 1982.

The rains in the Nairobi Area generally fall during 2 distinct periods, known locally as the long and short rains. The long rains usually occur from March to July and the short rains usually from October to December. The total rainfall is usually greater during the long rains; however, the short rains monitored in this study were greater in terms of total mm of rainfall than many previous long rains, including those of 1982. Daily rainfall data was recorded from October 1, 1982 to December 31, 1982 at the Karura Forest Station located 0.8 km SE of the study site. The degree of flooding (water level) in the dambo was recorded daily by measuring the water depth in mm at the lowest point in the seepage zone (the first area to flood). The flooding of dambo formations as described here is a relatively infrequent occurrence and may not occur over periods of several years, based upon local observations. The dambo did not flood during the previous long rain season.

Immature stages of mosquitoes were sampled with a pint (0.47 liter) dipper daily from October 19, 1982 (the first day of flooding) to December 31, 1982. Each day 100 dip samples were collected and transported to the laboratory. Samples were collected along 4 lines transecting the dambo by dipping equally in each of 3 predetermined zones to reduce the possible effects of non-random horizontal distribution of specimens. The zones (A,B,C) as shown in Fig. 3 were roughly defined as 3 concentric ellipses and were primarily distinguished by the type and amount of emergent vegetation predominating. Zone A contained abundant emergent *Typha domingensis* and *T. latifolia,* zone B contained no emergent vegetation and zone C contained abundant emergent *Eragrostis exasperata.* In the laboratory the larvae were separated by stage, counted and, when possible, reared to adults. The pupae were also counted and reared to adults. Subsamples of associated larval and pupal skins, whole larvae and adult male genitalia were mounted in Euparal® (G.B.I. Laboratories, England) and examined with a compound microscope to identify species using reference keys (Edwards 1941, Gillies and de Meillon 1968, Hopkins 1952, Mattingly 1971, Tyson 1970). Subsamples of associated reared males and females were mounted on paper points and examined with a dissecting microscope to confirm species identification.

RESULTS

The daily rainfall at and water level in the Karura dambo are illustrated in Fig. 4. During the 29 rainy days that occurred during the study period, 652.4 mm of rain fell on the Karura dambo. The first water in the dambo was observed on October 19 when the level was 55 mm. Between October 24 and December 3, the level gradually increased and the average depth during this interval was 410 mm. From December 4 to 7 the level increased to a maximum of 690 mm and then declined from December 19 to 31 to 150 mm. The water was cloudy and brown from the first to the 46th day following flooding (day 46), but from day 47 to the end of the study period the water color changed to a red to reddish-brown.

Between October 20 (day 1) and December 5 (day 47), 20,926 larvae and pupae were collected, separated according to developmental stage and identified. Figure 5 shows the daily total of immatures collected for each species during the study period. The mosquito species identified included: *Aedes (Aedimorphus) cumminsii mediopunctatus* (Theobald) (36%), *Ae. (Mucidus) sudanensis* (Theobald) (4%), *Ae. (Neomelaniconion) lineatopennis* (Ludlow) (22%), *Culex (Culex) quasiguiarti* (Theobald) (18%), *Anopheles (Anopheles) coustani* (Laveran) (3%) and *Cx. (Cux.) theileri* (Theobald) (17%). *Aedes cumminsii mediopunctatus* was first collected on

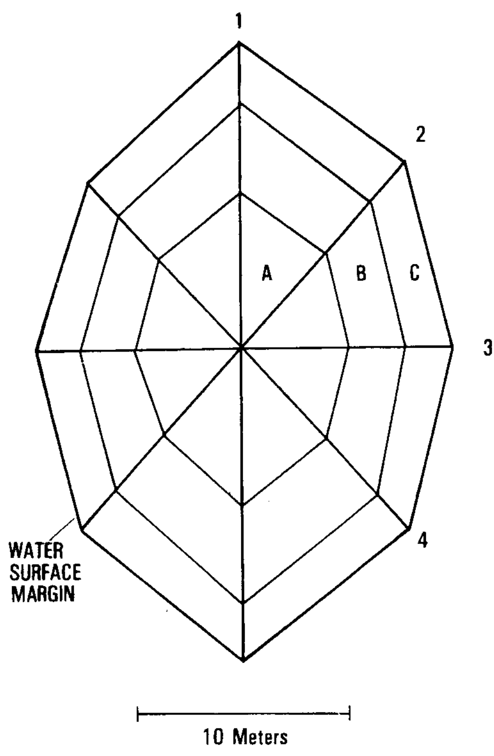

Fig. 3. Diagramatic overhead view of Karura dambo standing water demonstrating transecting sampling lines (1–4) and concentric collection zones (A,B,C).

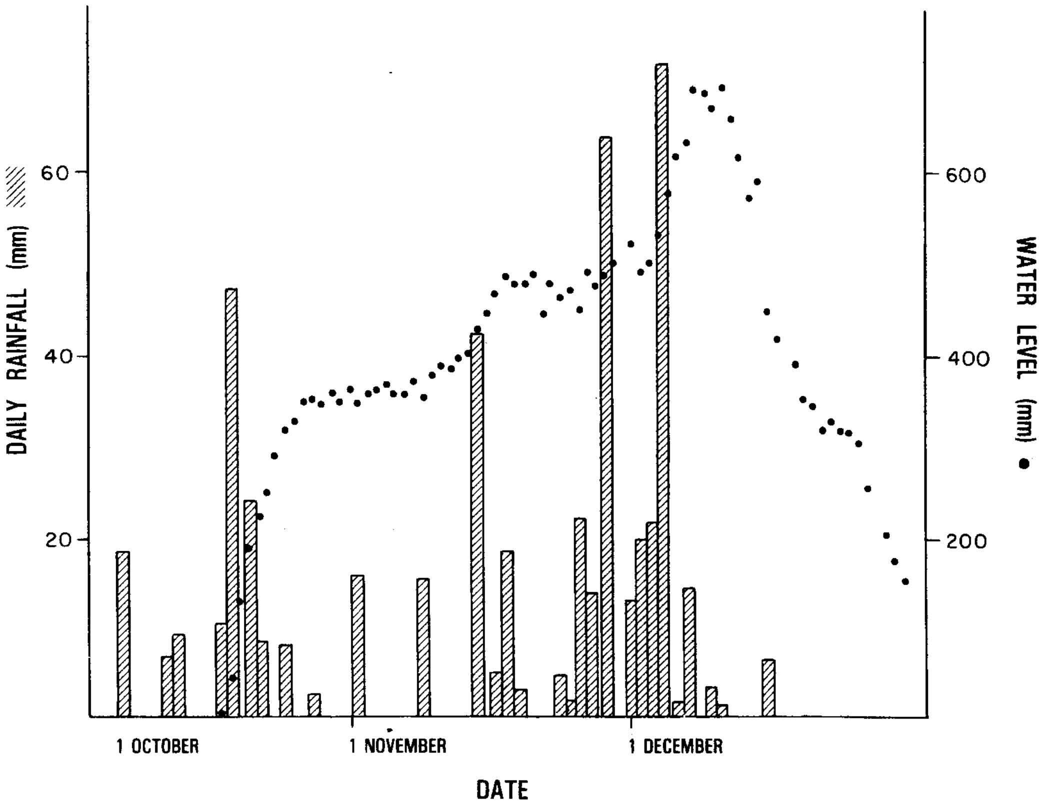

Fig. 4. Daily rainfall in mm (histogram) and daily flooding level in mm (dots) for Karura dambo.

day one and last collected on day 15 with greatest numbers occurring on days 4–9. *Aedes sudanensis* was collected on day 2 and persisted at a low level to day 29 with its largest collection (day 3) only 12% of that of *Ae. cumminsii mediopunctatus*. *Aedes lineatopennis* was first collected on day 9 and last collected on day 21 with peak populations on days 12 and 13. After numbers of the 3 species of *Aedes* dropped to zero they were not collected again during the study period. On day 15 the first *Cx. quasiguiarti* larvae were collected and its density remained fairly constant to day 30 whereafter numbers peaked on days 38, 42 and 46. *Anopheles coustani* larvae were collected on days 17 and 22, and starting again on day 30, its numbers remaining low to day 47. *Culex theileri* was not collected until day 33 but numbers increased rapidly to a maximum on day 47. On day 48 and for the next 26 days of the study no mosquitoes were collected from the dambo. Populations of *Cx. quasiguiarti*, *Cx. theileri* and *An. coustani* abruptly dropped to zero. Figure 6 illustrates, for each of the 6 species, the mean number of individuals of each developmental stage collected per dip on each collection day following flooding of the dambo. Table 1 lists the number of specimens of each stage collected and the percentage of the total number collected for each species.

DISCUSSION

The rainfall during the study period nearly equalled the previous 10 year mean yearly rainfall for the study area. The distribution and amount of rainfall prevented the dambo water level from dropping significantly during the study. The heavy rains of late November and early December may have caused excessive deposition of red laterite soil into the dambo and the resultant mosquito die off on day 48. The specimens of *Ae. cumminsii mediopunctatus, Ae. lineatopennis* and *Ae. sudanensis* collected were the result of a single, progressive and generalized flooding of eggs in the soil of the dambo. There is no indication that water recession and reflooding significantly contributed to population levels in any of the *Aedes* spp. Maximum numbers of *Aedes* first stage larvae were reached 1–3 days after hatching and declined rapidly thereafter. There was no recurrence of *Aedes* immatures following their brief population in-

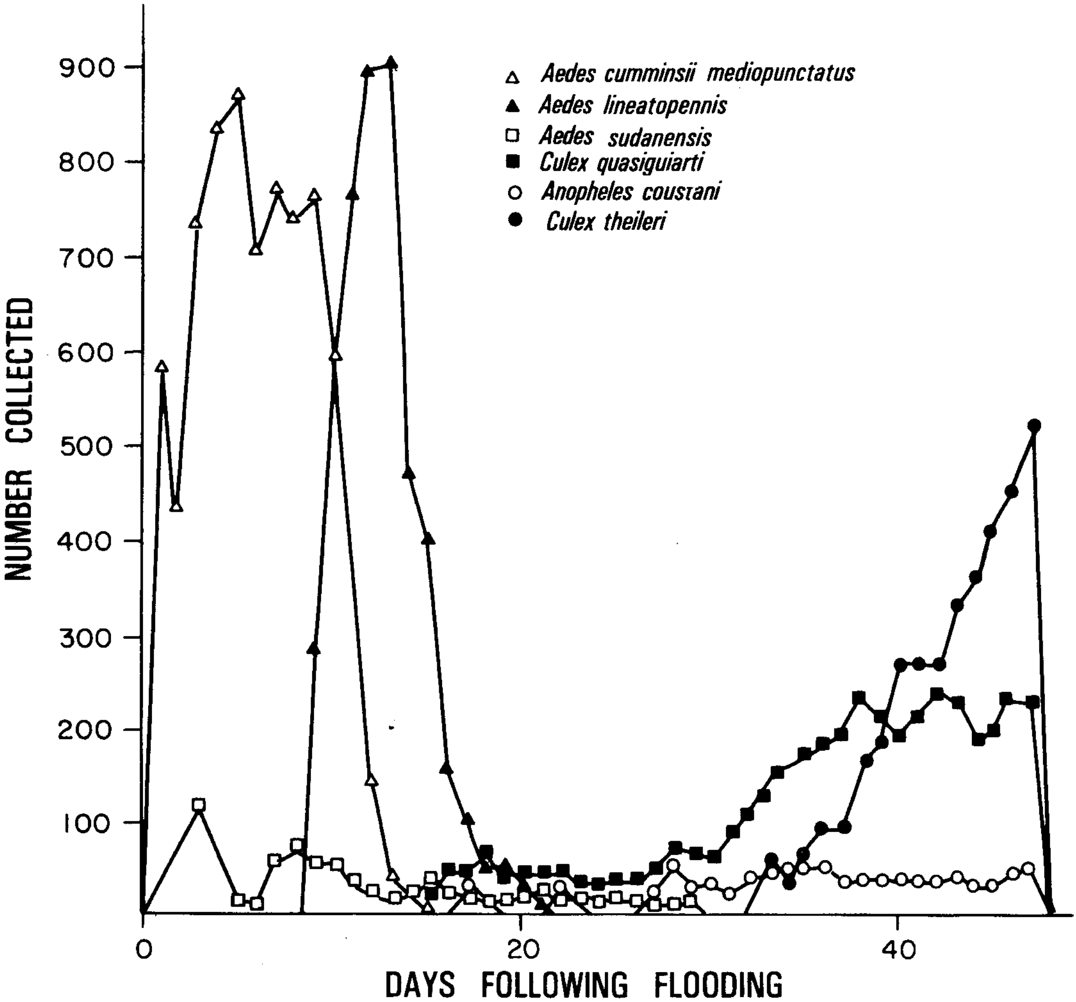

Fig. 5. Daily total of specimens for each species collected from Karura dambo.

crease and decline; each of these species disappeared after one generation. The occurrence of *Ae. lineatopennis* 8 days following *Ae. cumminsii mediopunctatus* may indicate that either the eggs of the 2 species required different hatching stimuli or that they were located in different areas of the dambo and were flooded at different times as the water level rose. Figure 4 shows that the water level had risen to a plateau coinciding with the appearance of *Ae. lineatopennis* on day 9. This suggests that the eggs of *Aedes lineatopennis* were located away

Table 1. The number of specimens of each stage collected and the percentage of the total number collected for each species.

Species	Larval stage 1st	2nd	3rd	4th	Pupae	Total
Ae. cumminsii	2489(33%)	2308(30%)	1560(21%)	817(11%)	407 (5%)	7581
Ae. sudanensis	316(43%)	148(20%)	107(14%)	96(13%)	72(10%)	739
Ae. lineatopennis	2003(43%)	1070(23%)	696(15%)	551(12%)	341 (7%)	4661
Cx. quasiguiarti	1613(43%)	1046(28%)	643(17%)	286 (8%)	124 (4%)	3712
An. coustani	186(25%)		525(72%)		42 (3%)	753
Cx. theileri	1730(49%)	723(21%)	575(16%)	379(11%)	91 (3%)	3498

from the center of the dambo in higher areas which flooded later. *Aedes sudanensis* required approximately twice the developmental period of either *Ae. cumminsii mediopunctatus* or *Ae. lineatopennis*. This is indicative of a long developmental cycle common to some predacious species. *Aedes sudanensis* was observed to be predacious in the field and it had to be provided with mosquito larvae in the laboratory as a source of nutriment. The development from first stage larva to pupa, as interpreted from Fig. 6, required 5–8 days for *Ae. lineatopennis* and 18–19 days for *Ae. sudanensis*. The occurrence of *Cx. quasiguiarti*, *An. coustani* and *Cx. theileri* 15, 17 and 33 days, respectively, following flooding and the general increase in population levels of all stages to day 47 indicate that these 3 species had successfully developed to adults and were producing multiple generations. Presumably, the absence of all mosquito immatures from day 48 followed some abrupt change in the aquatic environment of the dambo. Other aquatic ar-

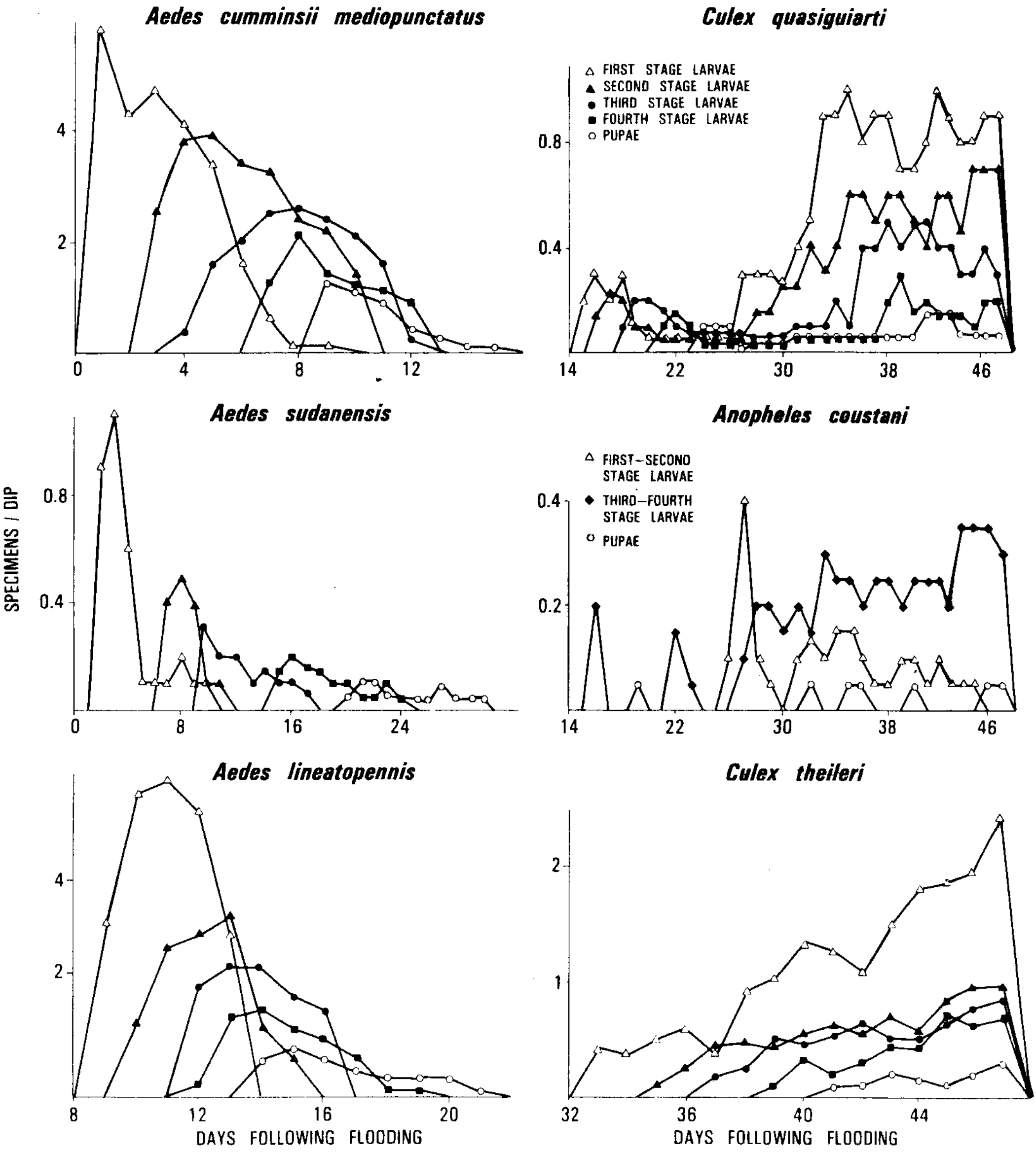

Fig. 6. Mean number of specimens collected per dip in Karura dambo for the developmental stages of *Aedes cumminsii mediopunctatus, Aedes sudanensis, Aedes lineatopennis, Culex quasiguiarti, Anopheles coustani* and *Culex theileri*.

thropods were also absent in collections after day 47. The appearance of first stage larvae of aedine species soon after flooding, compared with a delay of 15–33 days until the appearance of the *Culex* and *Anopheles* larvae and the occurrence of only one generation of aedine mosquitoes, are important observations with respect to determining field sampling strategies for mosquitoes during RVF investigations.

Rift Valley fever virus has been previously isolated from 3 of the 6 species encountered in the dambo. *Aedes lineatopennis* and *An. coustani* have been incriminated by McIntosh (1972) in Zimbabwe, and by Davies and Highton (1980) in Kenya. Gear et al. (1955) and McIntosh (1972) incriminated *Cx. theileri* in South Africa. McIntosh et al. (1980) have incriminated both *Cx. theileri* and *Ae. lineatopennis* in South Africa. The developmental cycles, the influence of environmental factors upon them, and particularly the conditions necessary to produce high population densities require further study to evaluate the role of these species in the transmission of RVF. Davies (1975) states that "the most interesting problem relating to RVF in Kenya and elsewhere has been to define the interepizootic maintenance cycle." This remains a fascinating problem in the natural history of RVF.

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