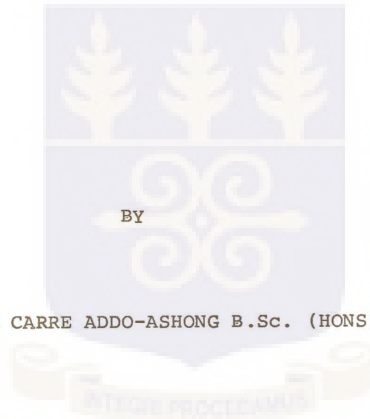


THE BIO-ECOLOGY OF AEDES AEGYPTI  
LINN., (DIPT: CULICIDAE) WITH  
PARTICULAR REFERENCE TO THE  
IMMATURE STAGES, AT LEGON  
AND SURROUNDING AREAS



BY

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This is to certify that this thesis has not been submitted for a degree to any other University. It is entirely my own work and all help has been duly acknowledged.

  
.....  
(Ruth C. Addo-Ashong)

Supervisor:   
.....  
W. Z. Coker

DEDICATION

.....to

Kwame, for allowing me to undertake this study  
and for his continuous love and support;

....to

Daddy, for advising me to pursue another degree  
course and for his love and concern;

....to

Mummy, Dave, Michael and Rachel for giving me  
moral support and affection throughout my period  
of study.

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## CHAPTER ONE

### GENERAL INTRODUCTION

1.0 Aedes aegypti Linn., commonly known as the Yellow Fever or Tiger mosquito has a world wide distribution within the tropical and sub-tropical zones including Africa and the Americas (Rice, 1913; Roy, 1954; Tinker, 1959; Christophers, 1960). Of the important human diseases transmitted by mosquitoes, namely malaria, yellow fever, dengue and diseases caused by the transmission of filarial parasites eg. Bancroftian filariases, Ae aegypti is the usual vector of yellow fever and dengue. From an epidemiological point of view the urban yellow fever is the most important since it is considered as an internationally quarantinable disease.

#### 1.1 Distribution

Extensive research has been carried out on the distribution of Ae. aegypti in Africa. Edwards (1941) observed in the Ethiopian sub-region of East Africa that the insect is cosmopolitan in the region and is very abundant in the urban areas. The biology, taxonomy and distribution of mosquitoes including Ae. aegypti in Kenya, Tanzania and Uganda have been reviewed by Mattingly (1953),

van Someren (1967) and van Someren et al. (1955).

Few records have been received from South Africa and Edwards (1941) attributes that apparent lack of information to the fact that Ae. aegypti is cold temperature sensitive with resultant low incidence of yellow fever outbreaks in these areas (Soper, 1967; Muspratt, 1965).

Ae. aegypti used to be very important and abundant in North Africa e.g. Morocco, Tunisia, Egypt and Libya and other areas around the Mediterranean Sea, but the numbers have decreased tremendously of late (Holstein 1967). He subsequently attributes this turn-about to development and urbanization improvement in hygiene and the wide extension of malaria control programmes in these areas using residual insecticides which could have had consequential effects on Ae. aegypti.

Literature from West Africa shows extensive work done on the ecology, physiology, taxonomy and distribution of Ae. aegypti in Nigeria (Dalziel, 1920; Dunn, 1927; Service, 1963, 1965; Surtees 1959; Hanney, 1960a; Boormann, 1961; Kumm, 1931). Reports from Liberia suggest that the insect exists in low numbers (Peters, 1957; Fox, 1958). W.H.O. epidemiology records (1980) show that the last reported case of yellow fever occurred in 1967.

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Aedes aegypti is cosmopolitan in Ghana. Available literature shows extensive research carried out in the Northern region (Ingram, 1912, 1919; Mouchet, 1971), south eastern region (Macfie and Ingram 1916; Macfie 1920; Chinery, 1965, 1969) and the Volta region by Coker 1961 (see McClelland, 1971). Most of the investigations were ecological, geared to its control.

1.2 Epidemiology

Yellow fever is an acute and fatal disease although recovery from it is followed by lasting immunity and second attacks are rare. It is highly communicable and its continual transmission is dependant on the inter-relation of the supply of the yellow fever virus, the density of Ae. aegypti and the availability of susceptible hosts (Soper, 1967). Since large numbers of mosquitoes in an area do not necessarily imply that an outbreak may occur, an epidemic may certainly occur any time a patient suffering from the disease is allowed to enter the area and become a source of infection for the mosquito. It is known that a yellow fever patient is capable of infecting mosquitoes only during the first 3 or 4 days after coming down with the disease. After the mosquito has bitten such a patient, a period of at least 12 days must elapse before the insect is capable of transmitting

the disease. The organism, having undergone its 12-day development renders the mosquito infective for life (Riley and Johannsen, 1938). Although not communicable by contact or common vehicle it is possible to transmit the virus by swallowing the infected mosquito or by crushing the infected insect on the body surface, the virus particle being capable of penetrating unbroken human skin (Snow, 1974).

Aedes aegypti is known to transmit dengue or breakbone fever as well (the life cycle of the dengue viruses is much the same as that of yellow fever) which is an infectious but not fatal fever. Notable epidemics have occurred in the Pacific islands, Southern Europe, Asia, in the United States and recently in the Carribean. (W.H.O. 1972; 1980).

Another epidemiological type of yellow fever called Jungle or Sylvatic yellow fever is normally a disease of monkeys which in Africa however, involves Ae. africanus and Ae. simpsoni. Sometimes other Aedes species e.g. Ae. vittatus and Ae. taylori are responsible for local transmission. Sylvatic yellow fever occasionally spills over into human populations when people living in tropical forests are bitten by infective mosquitoes; Ae. aegypti is still responsible for transmitting the disease from man to man.

The virus is however the same as that of urban yellow fever and one vaccination provides protection against both types of disease in man (W.H.O. 1972). Sylvan yellow fever is present throughout large parts of tropical America in the forest regions and throughout large parts of Africa south of the Sahara, and is thought to be endemic in those parts. Aedes aegypti is also known to transmit a filarial worm Dirofilaria immitis to dogs.

### 1.3 Taxonomy

Aedes aegypti is a moderately sized rather strikingly marked mosquito normally very dark although it is subject to much individual variation. The thorax has a conspicuous and characteristic broad silvery white curved line on each side with two indistinct slender broken lines between. This gives a lyre shaped pattern to the thorax. The legs are conspicuously banded (see Plate 1). Detailed work has been carried out by Summers-Connal (1927) and Mattingly (1957) and McClelland, (1971) who reported a range of colouration from black to almost white. A somewhat brown specimen originally found near Brisbane (Queensland Australia) by Bancroft has been given the varietal name 'queenslandensis' by Theobald (Edwards, 1941; Christophers, 1960). This Ae. aegypti var queenslandensis Theo., is now



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known to embrace any form showing bleaching of the dark scales from mud-brown through shades of buff to almost white. Other varieties include Ae. aegypti ssp formosus Walker, a form confined to Africa, south of the Sahara, and which is the only form known in this area except in coastal districts or in one or two inland trade frequented areas. This variety differs from the type form in the markedly black appearance of the dark areas of the thorax and the abdomen and in the absence of bleaching or extension of pale scaling on any part of the body (Christophers, 1960). The type form, Ae. aegypti is a brown form and is probably what Riley and Johannsen (1938) refer to as the American Ae. aegypti.

#### 1.4 Bionomics

Adults of both sexes of Ae. aegypti can live for several weeks or months with the female being longer-lived than the males. Both sexes however, live much longer in a moist environment. A single mating usually occurring within 2-3 days after emergence, ensures fertile eggs during the entire reproductive life of the female. Copulation normally takes place in flight and lasts less than a minute. Blood meals are essential for egg development and oviposition and the first meal is taken 1-2 days after emergence and subsequent

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meals at about 3 day intervals, (W.H.O. 1972).

The species is pre-eminently a domestic one found almost exclusively about the habitations of man. It is a vicious day biter although it occasionally bites at night. It persistently attacks man and in his presence will not feed on other animals. It attacks silently and usually approaches stealthily from behind and bites ankles, undersides of hands and arms or the neck region or the body. The humming sound of most other mosquitoes has been suppressed in the evolutionary process of Ae. aegypti adaptation to man (Riley and Johannsen, 1938).

Aedes aegypti larvae are (see Plate 2) known to breed in relatively clean water and has a decided preference for rain water (Christophers, 1960). Surtees, (1960) however concludes that Ae. aegypti breeds in a variety of micro-habitat and in a range of water conditions from clean to highly contaminated as found in water rich in decaying matter such as in tree-holes and rot holes. Similar reports have previously been made by others observing this adaptation to various natural habitats (Dalziel 1920; Dunn, 1928; Peters, 1957; Boormann, 1961; Service, 1965). In an experiment

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Plate 2: Aedes aegypti Linn., 4th instar larva

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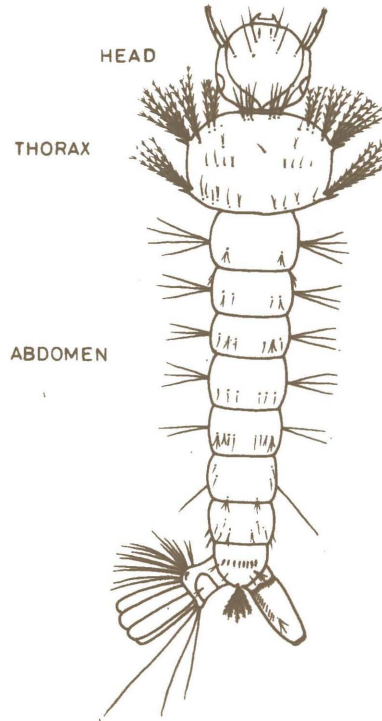


Plate 3: *Aedes acroati* Linn., larva (diagramatic)

carried out by Surtees (1960) in which a freely breeding colony of Ae. aegypti was allowed to oviposit in clean water and in water containing different concentrations of decaying vegetable matter, over 70% of the eggs were laid on the clean water. In water containing the contaminations, fewer eggs were laid as the contamination increased. The adaptation of this species to various man-manipulated and some natural habitats for oviposition and larval development is well known, with both eggs and larvae having been collected from many temporary water habitats, such as water in flower pots and vases, various water receptacles, barrels, ant traps, discarded tin cans, broken bottles, coconut shells, old tyres, leaf axils, fallen leaves, and water in tree-holes and rock pools (Sheppard et. al. 1969; Tinker, 1967; Chiner-y, 1969; Chan et. al. 1971; Macdonald and Rajapaksa, 1972; Rao, 1973).

This brief discussion shows that Ae. aegypti definitely constitutes an economic threat to man as far as public health is concerned. It has been pointed out that total eradication of Ae. aegypti is not necessary to control yellow fever outbreaks but if the mosquito occurred in less than 5 per cent of the houses, the inhabitants were reasonably safe (Soper 1967).

Transportation and urbanisation are the major causes of the spread and increase in prevalence of Ae. aegypti. The immature stages get easily transported to new areas where the disease has not hitherto existed or had been eradicated, (Surtees, 1967).

#### 1.5 Control of Ae. aegypti

It is therefore desirable to educate urban dwellers on preventive or simple precautionary measures like preventing the unnecessary collection of stagnant water in and around houses, and improved sanitation generally to reduce the abundance of the mosquito.

Anti-Aedes aegypti campaigns have been carried out successfully in many parts of the world where yellow fever was liable to occur in an epidemic form. (Soper et. al. (1943) have given detailed accounts of the eradication of this species in Brazil. The eradication and control of Ae. aegypti in Texas is given by Chandler (1956). Another successful eradication campaign using Abate (Temephos) as a larvicide in potable water for intradomiliary and extradomiliary treatment on Cayman islands was carried out in 1970/71 (Nathan and Giglioli, 1982). Mouchet (1971) also used this chemical to eradicate Ae. aegypti in the drinking containers in Northern Ghana.

Physiological resistance of Ae. aegypti to DDT and dieldrin has been observed in the Carribean areas, South America, West Africa and South East Asia. The control of the species has therefore been hampered by its resistance to DDT and other organochlorine insecticides (W.H.O. 1967, 1972). Tests with DDT resistant Ae. aegypti to Abate however produced an effective kill. As the threat of an outbreak of yellow fever is always present whenever Ae. aegypti is present and because of this developed resistance, it is of utmost importance that the biology of this mosquito be re-assessed so as to enhance more modern methods of control and ultimately the eradication of this vector.

#### 1.6 The medical importance of Aedes aegypti as a vector of yellow fever

Yellow fever was until the early years of the present century one of the most dreaded of epidemic diseases. It is normally regarded as an African or American disease (Roy and Brown, 1954). It is a communicable disease but non-contagious and is characterised by a sudden onset of a fever like jaundice, vomiting, nausea and prostration of which the causative agent is a filterable virus.

Although the effects are so fatal it was not until the 19th century that research was started on it. And here credit should be given to Dr. Carlos Finley (1811) who was one of the first people to postulate the existence of a transportable substance which caused the illness and showed through a series of experiments that Ae. aegypti was the vector (Roy and Brown, 1954). Reed, Carrol, Argamonte, Lazear and Finley showed the exact method of spread of the disease (Riley, 1938). Another important yellow fever investigator who was killed by the disease was the Japanese Hideyo Noguchi who died in Accra in 1924.

In the earlier years doctors probably recognised the disease as an ordinary fever or malaria, a jaundice, black-water fever or gastritis and it is suspected that there could have been more cases of yellow fever which were incorrectly diagnosed (Yellow fever bureau, 1911). Now with the advancement of medical science yellow fever can be cured if recognised in the initial stages.

#### 1.6.1 Yellow fever in West Africa

Yellow fever was thought to be endemic in West Africa because whilst Africans suffered in a mild way foreigners were more susceptible to it.

In 1913 Rice, in a telegram to the Yellow fever bureau headquarters wrote "..... I considered yellow fever to be endemic amongst the native population of West Africa and I am still of that opinion. There is no other hypothesis that to my mind can explain this and previous outbreaks". Similarly in all the fatal cases reported in Accra and Seccond~~e~~ (Sekondi) the victims were Europeans only.

Beeuwkes et. al. (1933) carried out extensive investigations on the West Coast of Africa and concluded that although the climatic conditions of the Gold Coast (Ghana) were favourable for breeding, advanced sanitation (due to the wealth of the colony) had kept numbers of the vector low as compared to Nigeria. In 1910, Freetown, Sierra Leone was considered a hot bed of yellow fever. Evidence has it that yellow fever is not really a disease of the past as within the last 20 years there have been cases reported from Senegal in 1965 (243 cases), Upper Volta (87 cases) and Nigeria (208 cases) in 1968, Sierra Leone in 1975 (130 cases) and Ghana in 1979/80 (823 cases) (Anon 1980; Service 1983 in press).

### 1.6.2 Occurrence of Yellow fever in Ghana

One of the most important epidemiological events to occur in Ghana during 1977-80 was the outbreak of yellow fever and this has been the largest since 1901 and a major one as there were more cases of the disease reported within this period than all the cases since 1901 - 1960 put together (Ministry of Health 10 year report on epidemiology, 1980 see Table 1).

The last major epidemic of yellow fever occurring in 1969-70 was limited to the Upper and Northern regions. Out of the 318 cases reported there were 79 deaths (24.8% case fatalities), the most affected towns being Jirapa and Nandom. Previously Boormann and Peterfield (1957) had reported an outbreak of the disease in Kintampo.

Dr. Mouchet (Mouchet, 1971) a W.H.O. consultant investigated the 1969/70 outbreak by carrying out surveys to determine the potentialities of the vector. He concluded that due to the cultural methods of the ethnic group yellow fever was liable to become established unless proper sanitation was enforced.

Incidences of the disease in the following years were relatively low except for a few towns to which yellow fever

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is thought to be endemic e.g. Dormaa Ahenkro and some other towns at the periphery of the hyper-endemic core for yellow fever in Brong Ahafo (Agadzi, 1982). The total number of cases reported were 10 (see Appendix 1).

Table 1 reveals that 5 out of the 9 regions were affected the heaviest mortalities were recorded in the Volta and Eastern regions. The epidemic struck in the dry season during which much water was stored in receptacles. As observed by an epidemiologist assigned to that project the 10 year immunization period afforded by the vaccination had expired since the last epidemic in 1969/70 when mass vaccination programmes were carried out. An analysis of the disease by age showed that children under the age of 14 years were not affected a fact associated once again with the immunization campaign in 1969 in which that cohort of children were vaccinated.

Jirapa (Upper region) has large groundnut farms and monkeys (possible reservoirs of the virus) from surrounding forests come to the farm to feed on the nuts. Entomologist present at that time identified the vectors as Ae. aegypti and Ae. simpsoni which are well known for the part they play in urban transmission of yellow fever from a sylvan source (W.H.O. 1972).

Table 1

Yellow fever notification by the regions  
in Ghana, 1977-1979\*

| Year | Region      | No. of Cases | No. of deaths | Cases fatalities % |
|------|-------------|--------------|---------------|--------------------|
| 1977 | Upper       | 108          | 31            | 28.7               |
|      | Brong Ahafo | 1            | 1             | 100.0              |
|      | Totals      | 109          | 32            | 29.0               |
| 1978 | Upper       | 28           | 3             | 10.7               |
|      | Eastern     | 32           | 12            | 37.5               |
|      | Volta       | 159          | 25            | 15.7               |
|      | Totals      | 219          | 40            | 18.7               |
| 1979 | G. Accra    | 2            | 2             | 100.0              |
|      | Eastern     | 207          | 44            | 21.0               |
|      | Volta       | 181          | 28            | 15.5               |
|      | Brong Ahafo | 104          | 46            | 44.0               |
|      | Totals      | 494          | 120           | 24.0               |

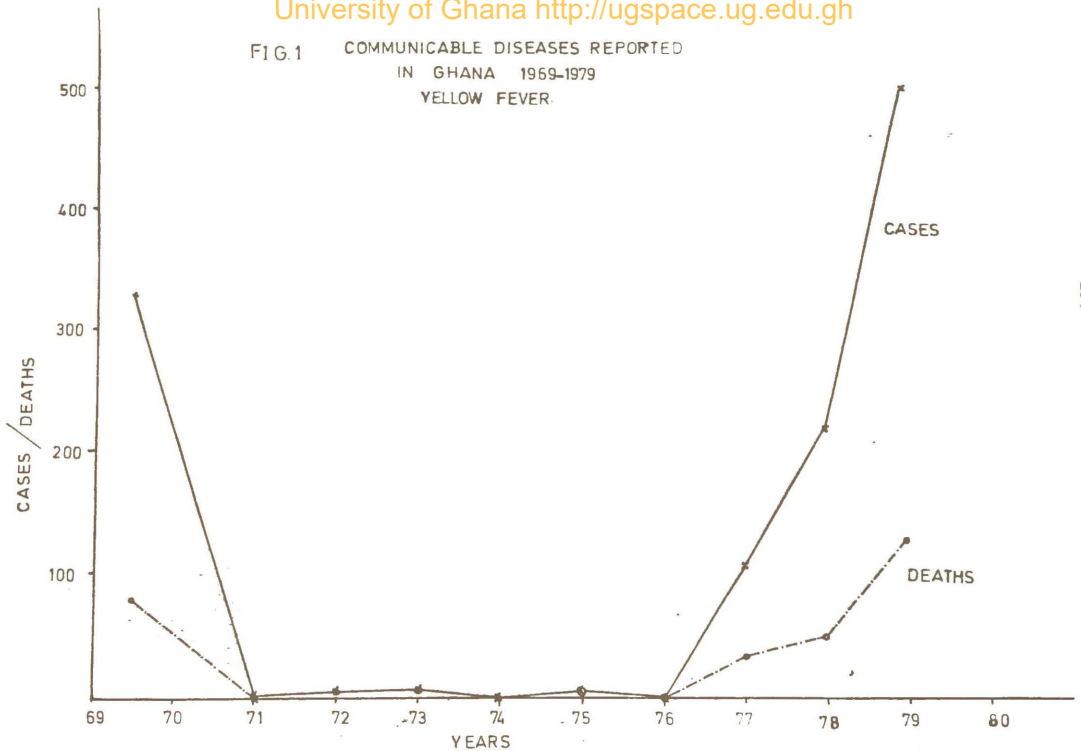
\* Ministry of Health 10 yr. Epid. Report.

The epidemic at Maase (Eastern region 1978) occurred in the rainy season. Soon after cases appeared in Brong Ahafo and in the Volta regions. An irregular chronological manner was thus observed as the disease peaked either in the dry or wet season, and thus prompted Agadzi *et. al.* (1982) to conclude that there did not appear to be any seasonal pattern to the epidemics.

The 10 year cycle of the vaccination is seen in Fig. 1 and in Appendix 1 which show the peak epidemic seasons and the quiescent periods in between. The 1977 - 79 epidemic was the more severe and caused great concern to epidemiologists who in a control campaign expect total recovery and consider a loss of 5% as acceptable, and not higher percentages as observed in some regions. It is hoped that due to the mass immunization, immunity would be afforded for a few more years but should be noted that not all the regions were covered.

This present work therefore attempts to update existing knowledge on certain aspects of the ecology and biology of Ae. aegypti and other mosquitoes closely associated with it. Emphasis is laid on the survival ability of

FIG.1 COMMUNICABLE DISEASES REPORTED  
IN GHANA 1969-1979  
YELLOW FEVER.



the eggs, larvae and adults stages of the vector in its natural breeding places through studies on the effect of adverse environmental conditions, predation and life history budgets. An investigation lasting 15 months was carried out to find the contribution of these environmental conditions in determining preferential breeding sites, distribution and seasonality in Accra the capital of Ghana and surrounding villages.

The project seems a worthwhile undertaking as until sanitary conditions are improved and effective piped water supply installed in developing countries the presence of Ae. aegypti and subsequently yellow fever will be a continual hazard.

CHAPTER TWO

LOCALITIES AND CLIMATOLOGY

2.0 Introduction

It is important to take into consideration the habits and occupation of people in a particular area of study when dealing with Ae. aegypti, as this mosquito has been recognised as a peridomestic breeder occurring in large numbers where human settlements are found (Hamlyn-Harris, 1927; Christophers, 1960; Tinker 1967; Chinery, 1971; Service, 1976).

The breeding sites of Ae. aegypti like several other species of the sub-genus Stegomyia were originally tree-holes, but the insect has become more or less domesticated and has adopted water containers as breeding sites (Dalziel, 1920; Carter, 1924; Dunn, 1927; Riley and Johannsen, 1938; Soper, 1967; Chan et. al. 1971). It seldom breeds in any natural collection of water and for some unknown reasons, it prefers temporary, small artificial collections which contain reasonably clean water. Many authorities however differ in their opinions as to the amount of organic pollution Ae. aegypti can tolerate. Ingram, (1919) reported that the species definitely bred in clean

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water. According to Graham, (1911), however there was no preference as the insect bred equally in dirty and clean water. It has never been found breeding in water\*polluted with urine or feaces (Mhasker, 1913; James, et. al. 1914). Aders (1917), reported that Ae. aegypti can exist in water with a poor food supply.

Three areas of study were chosen<sup>based</sup> on their location, climatology and type of community, and because some of the most difficult obstacles to improving water supplies at a low cost in a rural African setting are present in two of these areas. Field studies were carried out at Danfa, a small village off the main Accra-Aburi road and at Amasaman, a medium-sized but very busy town on the Accra-Nsawam road. Both field and laboratory studies were also carried out at the University of Ghana campus, Legon. (see figs 2 and 3).

## 2.1 Localities

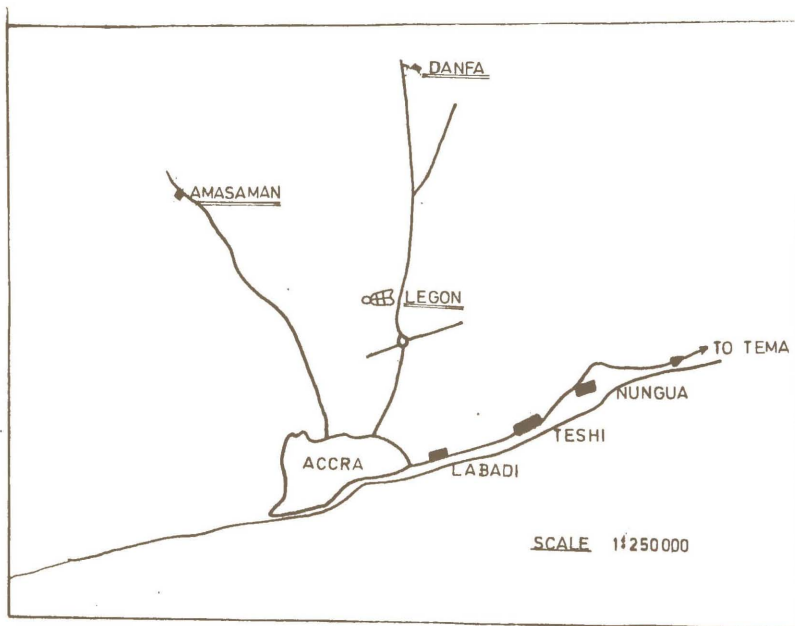
### 2.1.1 Danfa

Danfa is a small farming village off the main Accra-Aburi road and lies on latitude  $5^{\circ}.47$  min. N and longitude  $0^{\circ}.10$  min W. It has a population of about 800 inhabitants mainly of the Ga-Adangbe tribe. It is situated at the

FIG 2 MAP OF GHANA SHOWING SAMPLING AREAS



FIG. 3 SAMPLING AREAS



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southern most portion of the Akwapim-Togo mountain range. The vegetation exhibited there is mainly of bush and patches of shrub with a few coconut palms, (Boateng 1970). The topography is a low hilly area with mainly red muddy soil in most places.

Danfa was made popular by the extensive work on rural health development conducted there by the University of Ghana Medical School in collaboration with the University of California at Los Angeles, U.S.A. The combined effort culminated in the erection of a clinic that serves most of the surrounding villages.

The principal occupation of the people is farming and those who do not work on their private farms, work at the Ministry of Agriculture Dairy Farm, at the clinic or the nearby local gin distillery. The women folk stay at home cook, sew, or prepare foodstuff e.g. gari for sale at the markets. A few of the people work in Accra.

The village itself is very simple and consists of, mainly baked mud bricks with thatched roof houses and a few cement houses with corrugated aluminium roofing sheets, (see Plate 3).



Plate 3: A typical compound house at Danfa. Part of the building is made of bricks and the other part of mud. Note the uncovered water receptacles in the yard.

There is a church and a primary and middle school. Electricity is non-existent and pipe borne water a mere dream as there are three non-functional standing water pipes.

Except for the thin layer of top soil, Danfa lies on hard pre-cambrian rock that contains few aquifers. As a result there are few opportunities for hand dug or machine drilled wells. There are no rivers and just one stream which allows the easy development of gravity fed reservoir systems (Danfa Project Final Report 1979). A pond was therefore constructed in 1961 through communal labour (Whyte 1971).

During the wet season run-off water collected from the roof into barrels is stored for household purposes. Each house has several water containers made of either clay cement, metal or plastic. The water containers are found on the verandah or even inside the living rooms. They may be covered with a lid, or kerosene is poured on the surface to prevent insects breeding in them. The containers are seldomly cleaned out until they are extremely dirty, full of sand or leaves and other debris. Both adults and children have access to the barrels.

2.1.2 Amasaman

A busy town about 12 km from Accra lies on latitude  $5^{\circ}.42$  min N and longitude  $0^{\circ}.17$  min W, on a low plain flat land having a sandy type of soil. The town, situated on the main Accra-Nsawam-Kumasi road, is a very active one because it has a railway station and thus a busy market. The population is about 1,500 to 2,000 and there are several tribes living together, mostly Ewes, Northerners and Gas. Most of the houses are made of cement although mud houses can still be seen.

Amasaman has a clinic, a court house, a post office, a petrol filling station, churches, schools, a night club and a large tractor assembling plant. Consequently, most people are engaged in some trade or salaried job and a few work in Accra. Farming, including poultry and livestock keeping still remain the main occupation of the illiterate people. There is electricity although many people still use kerosene lamps.

There are four main standing pipes which are non-functional and people fetch water from a near by hand dug out pond which happens to be larger than the pond at Danfa, (See Plate 4).



Plate 4: Little children fetching water for domestic purposes from the reservoir at Amasaman.

As at Danfa most houses have receptacles for storing water. Both children and adults have access to these water receptacles which are filled nearly every day. An interview with the people revealed that they normally added kerosene or alum to the water or simply covered them with tightly fitting lids in an attempt to purify and rid water of all organisms.

The soil is richer and the bush cover thicker than at Danfa.

People in this town as a whole are urban in outlook than the inhabitants of Danfa.

### 2.1.3 Legon.

A very modern University campus is situated at Legon at latitude  $5^{\circ}$ . min N and longitude  $0^{\circ}$ .13 min W. The population is about 5,000-6,000 people when the academic terms is in session. Both electricity and pipe borne water are available. The drainage system is very good and there are hardly any water storing receptacles or stagnant drains or pools. Most of the laboratory work was carried out there. The only field work conducted there was in the natural habitat of the mosquitoes i.e. tree-holes and discarded tins.

## 2.2 The Climate

The mean monthly precipitation is of great importance in this study because the basic criteria for the presence of mosquitoes is water. As such the abundance and distribution of many species is based on a large extent on available water for oviposition and larval development. Some authorities believe that the abundance of Ae. aegypti is not dependant on rainfall patterns, but in villages where the only source of water is rainfall or from reservoirs (filled by rain) there should be some correlation as in the drier months, water is stored for longer periods than in the wet season offering breeding sites and thus enhancing the domestic population. In the wet season however there are abundant potential breeding sites for the feral population. Mattingly (1971) defines the domestic population as that which breeds continuously, independent of natural rainfall cycle in water stored by man and the feral population as that which is determined by the natural rainfall cycle and is not dependent on (though not necessarily uninfluenced by) human activities.

All the experimental sites occur within the Accra plains which is known to be one of the driest zones in Ghana, having an average annual rainfall between 60cm in

the southern part to 100cm at the border of the Akwapim range of mountains. Data reproduced here were all supplied by the Ghana Meteorological Services.

The Meteorological Station nearest Legon, Mpehuasem, (a 5 year average) shows two main rain peaks, the higher one occurring in May/June and the second dry period in August.

Danfa (10 year average) also shows the two maxima for rainfall. The first is in May/June and the second shows a wet period stretching from September through November although total precipitation in the latter is much lower. Driest periods are December-February.

The nearest station that could be obtained for Amasaman was located at Pokuase and since these towns are a mile apart it is considered that values are representative of the climatic conditions at Amasaman. The wettest months are in May-June and in October and the driest December-January. Rainfall for these areas are exhibited in Figs. 5 and 6.

Figure 4 shows the mean maximum and minimum and mean monthly temperatures in Accra over a 10 year period. Highest temperatures are experienced in January-April whilst the lowest occur in June-September. Relative

Fig. 14

GRAPH SHOWING 7 Yr. AVERAGES AND MONTHLY RAINFALL, RELATIVE HUMIDITY AND TEMPERATURES IN ACCRA.

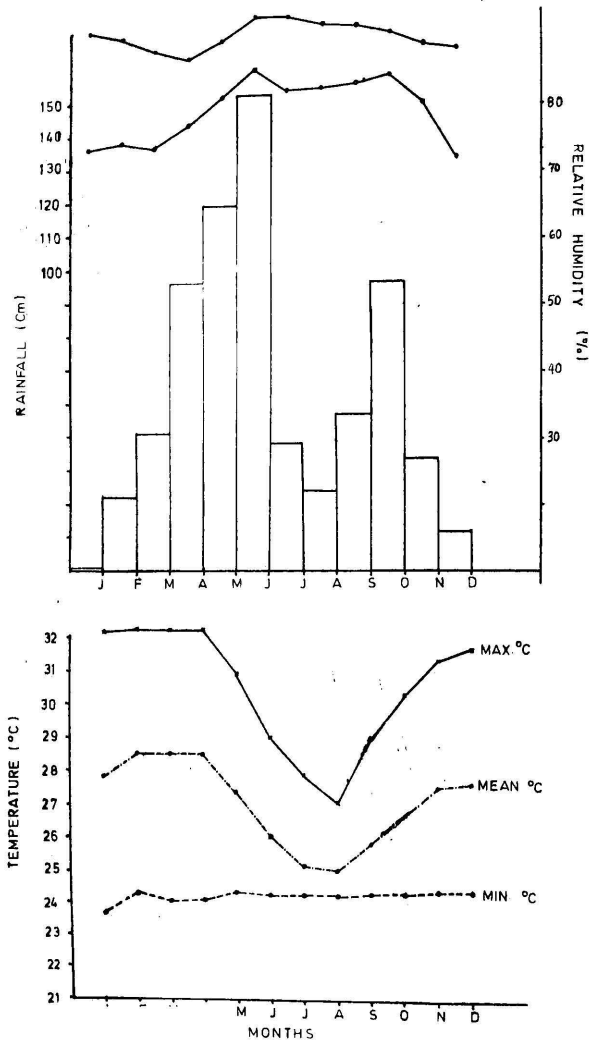


FIG. 5 GRAPH SHOWING RAINFALL AVERAGES FOR DANFA (10yr. AVERAGE)  
AND MPEHUASEM (6yr. AVERAGE)

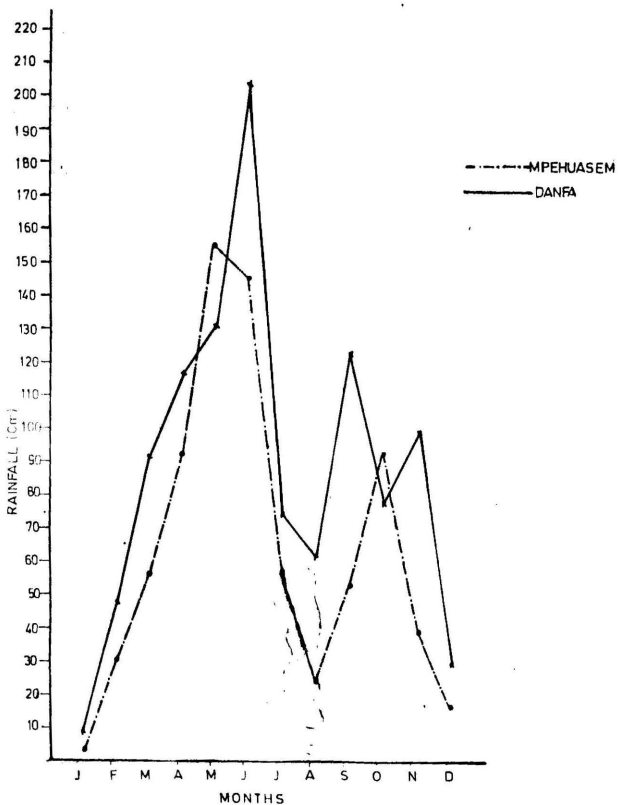
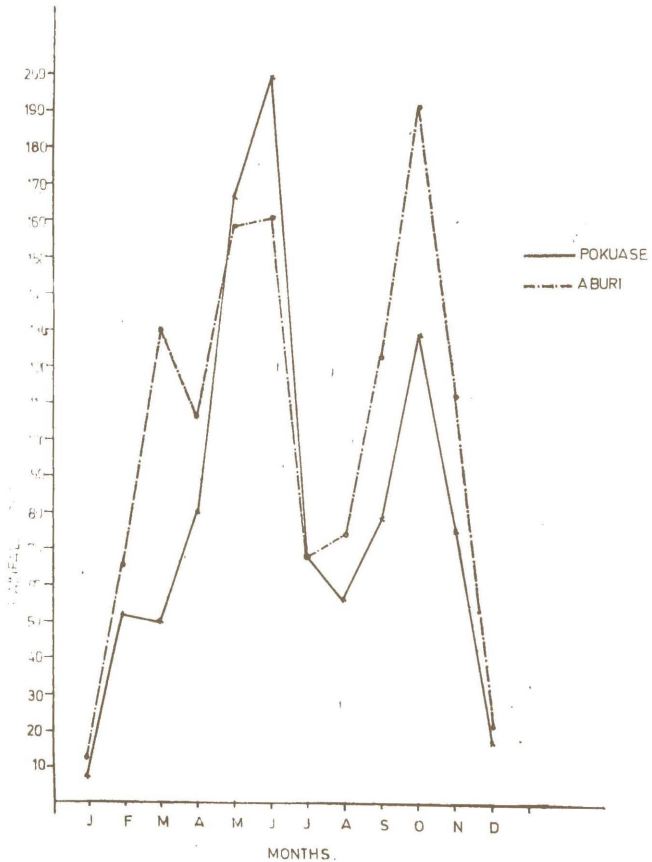


FIG. 6 GRAPH SHOWING RAINFALL RANGES FOR POKUASE AND ABURI WITH A 7yr AVERAGE.



humidity exhibited are also recorded and with Accra, afternoon relative humidity regimes are highest in May-September (1500 hrs), and morning regimes highest in June-September.

The relative humidity regimes exhibit an inverse relationship with that of temperature showing that the hottest period of the year has the lowest humidity and the reverse is also true for the coolest periods of the year.

An integration of these factors shows that a few distinct seasons can be recognised :-

- (1) a hot wet season extending from March to April and October-November. This is well exhibited in Danfa where the wet season starts in September. The humidity is however low and the highest evaporation losses from the ground surface occurs during this period. The rainfall is known to be heavy but short lived.
- (2) a cool wet season May-June and September for most of the villages. These periods are characterised by light showers of long duration. The winds are moderately strong.

- (3) a cool dry season starting late July through August with very little rainfall.
- (4) a hot dry season or the harmattan season which stretches from December to February. This is the driest period of the year as far as rainfall and humidity values go and temperatures are very high with the highest maximum temperature occurring in these periods.

Danfa however, being at the foot of the Akwapim mountains is greatly influenced by the climate there (see Fig. 5) and the actual drainage area of the reservoir is influenced by rain from the mountains more than by the strict dry climate of that which is typical of the Accra plains. Meteorological data obtained from Aburi are therefore shown in Fig. 5 to give an idea of the effect of the mountain range on Danfa. Aburi has more wet months and a higher annual rainfall.

CHAPTER THREE

OBSERVATIONS ON THE IMMATURE STAGES  
OF Aedes Aegypti

3.0 The Effects of the adverse environmental conditions of desiccation and temperature.

3.1 Introduction

Atmospheric humidity is often of great importance in limiting the times and places where insects are most abundant. Specific humidities and temperatures are vital for functions like oviposition and egg hatching. A precise study of the water relation, water balance and temperature will increase knowledge about this insect and enhance its ultimate control.

Eggs of Aedes sp. can withstand long periods of desiccation and other harsh environmental conditions (Christophers 1960). The problem is however to find out how long they can withstand these conditions and how severe the conditions can be.

Disagreements also exist as to the number of eggs a female may lay. Christophers (1960) records a range of between 80 - 120 at one oviposition, Connor (1924) 35 - 100, and Roy (1936) an average maximum of 76. Buxton and Hopkins (1927) report of as few as 20 eggs at a time in the field. The ovaries of Ae. aegypti consists of a large number of

ovarian tubules in which successive follicles develop into eggs. Christophers (1960) records as many as 120 follicles in the ovaries and therefore expects an average of 100 eggs at a time.

A number of experiments have been carried out to find the effects of adverse conditions of temperature on the different stages of Ae. aegypti. Macfie (1920) and Bar Zeev (1958) record the survival duration of various stages of Ae. aegypti after exposure to high temperatures. It would be of interest to find out any other temperature extremes since high temperatures can be achieved in the tropics. Bacot (1916) reported egg viability after storing for 262 days and Francis (1907) after 4 months. Earlier workers rarely stated the exact experimental conditions worked in. Christophers (1960) however gave results of eggs stored at a specific temperature and R.H. and obtained results that at 25°C and 70% R.H. eggs could be kept for 12 months. Of more recent times Fox (1978) reported from Cuba that eggs of Ae. aegypti could be maintained at 68°F-78°F (21-26)°C and 45-60% relative humidity for about 18 months. The fact that a few eggs (<1%) did survive shows that some eggs may survive for 18 months in a dry habitat

and more considerations should be given to this fact in executing control programmes.

The present work was undertaken to determine survival of Ae. aegypti eggs during periods of storage under different relative humidities and the effect of different temperatures on the larvae and pupae, a short investigation was conducted to find out the number of eggs laid at oviposition.

### 3.1 Experimental Methods

#### 3.2.1 Eggs : Relative Humidity

Adults were kept in a rearing cage (see Plate 5) and provided with 10% solution of sucrose soaked in cotton wool as food. At 2 day intervals the author's hand was offered to them to bite. After feeding adults that were to be used in the egg laying experiment were isolated into 3 x 1cm. glass tubes which had a wet pad of cotton wool in it. On top of this pad was a disc of wet filter paper which served as oviposition sites. A male was introduced into each tube, to ensure fertile eggs. The tubes were each covered with a piece of gauze. Eggs laid after each feed were counted and the disc of paper changed.

To obtain large quantities of eggs for the Relative Humidity experiments, a petri dish lined with a wet pad of



Plate 5: Rearing Cage

cotton wool which was in turn covered with filter paper was also placed in the cage. Eggs were laid on the filter paper within 3-4 days. The eggs were kept moist for at least 60 hours and the filter paper was then air-dried for at least 24 hours. The dried filter paper was examined under a microscope, labelled and put into jars which were placed in the appropriate desiccator. This procedure was carried out over a period of time to obtain eggs laid at different dates in each desiccator and to obtain a large collection in each humidity regime.

Egg batches were removed periodically and according to the date on the labelling, the duration of desiccation was calculated. This was done with as much care as possible so as not to disturb the attained R.H. equilibrium.

Eggs on removed filter paper are counted several times and the averages taken since eggs are often laid in clusters and counting is difficult. The condition of the eggs were also recorded. They were then quickly submerged in tap water to which food was added and after 24 hours the number that hatched was recorded and the percentages calculated. The filter paper was then air-dried for 24 hours and resubmerged in water with food to determine whether any more

eggs would hatch. This drying and submerging was done at least three times to ensure that the hatching stimulus was adequate.  $\chi^2$  tests were carried out to determine whether there was any significance between percentage survival after increasing periods of desiccation.

#### 3.2.1.1 Methods of atmospheric control

Relative humidity can be defined as the ratio of Actual Vapour pressure to the Saturation Vapour pressure at the same temperature, expressed as a percentage. In practice, relative humidity values can be measured using a dry and wet bulb thermometer or a hydrometer. The presence of any dissolved salt lowers the Vapour pressure over the solution. If it is saturated, it even more certifies that the air over the solution has a definite humidity if the temperature is known. Therefore to obtain the different experimental solution, saturated solutions of potassium hydroxide were prepared using values from the International critics table (1928) (see Appendix 2). Graded solutions were then prepared to give relative humidities of 80, 60, 40, 20, per cent. 200ml of each solution was then poured into separate desiccators and placed in an atmosphere of 20°C. To cross-check that correct humidities had been

obtained, the experimental set up was left for at least a week to allow an equilibrium to be established; a sensitive electronic hydrometer was placed inside the desiccators to check the relative humidity.

### 3.2.2 Effects of Temperature

To test the ability of certain immature stages to survive high temperatures, groups of 20-50 first, or fourth instar larvae and pupae were exposed to various temperatures for various periods of time. Pupae used for these experiments were all more than 12 hours old. The numbers that appeared moribund or dead after the treatment were recorded. A water bath was used to ensure uniform temperatures of 40, 45, 48, and 50°. The larvae / pupae were put into a beaker and were immersed in the water bath and some of the water at the required temperature was poured over them. It was important to ensure that the temperature of the water in the beaker is the same as that of the water bath. After the experimental time (2, 5, 10, or 60 min.) the beaker was removed and immediately the water was drained and ordinary tap water (27°C) was poured on to the larvae/pupae. A 24 hour recovery period was allowed. The initial state (after the experimental time) and the final state (after 24 hour) of the

larvae/pupae were noted.

### 3.3 RESULTS

#### 3.3.1 Eggs: Numbers laid

Table 2 gives the number of eggs laid by 40 females after a single blood meal. The range of eggs laid was 53-96 per female and the mean  $68.6 \pm 2.48$  which is much lower than expected. Previous authors all recorded higher mean values (Christophers 1960).

Table 2

Number of eggs laid per female after a single blood meal

| No. of eggs per batch             | 50-59 |       | 60-69 |       | 70-79 |       | 80-89 |       | 95-99 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                                   | 50-54 | 55-59 | 60-64 | 65-69 | 70-74 | 75-79 | 80-84 | 85-89 | 95-99 |
| No. of females that fall in range | 4     | 2     | 10    | 9     | 3     | 7     | 2     | 1     | 2     |

#### 3.3.2 The effect of different relative humidities on eggs.

Results of the effect of desiccation on eggs after lengthy periods of storage are recorded in Table 3-6. The results are similar to those of previous workers (Christophers

1960, Service 1977) and they generally show that eggs of Aedes sp. can withstand adverse humidity conditions for a long time.

In each Table, columns a, b, and c, are the total numbers of eggs exposed for a similar length of time. This is so because different egg batches were hatched at various times (Column c).

Table 3 shows that eggs exposed to R.H. 80% were viable after a long time. During the first 26 weeks percentage hatch was very high (54.28%) suggesting that high humidities favour the viability of the eggs. Viable eggs in this regime hatch almost immediately and 2nd and 3rd soakings are not required.

An atmospheric humidity of 60% (Table 4) also supports viability. After 20 weeks a high hatch (63.36%) was still observed. Second soakings were often required to get all diapausing eggs to hatch.

A high percentage of eggs (55.32%) could tolerate 9 weeks of a 40% relative humidity atmosphere (Table 5). After that eggs lost their resistance and collapsed.

Table 3

Percentage survival of *Aedes aegypti* eggs exposed to a Relative humidity of 80 per cent over a period of 12 months

| Duration Weeks | Total No. of Eggs | Total No. of Larvae | % Survival | Percentage survival of individual batches | Description/Remarks           |
|----------------|-------------------|---------------------|------------|---|-------------------------------|
| 1              | 35                | 35                  | 100.00     |   | Fresh                         |
| 2              | 114               | 88                  | 77.19      | 86.5, 67.9                                | "                             |
| 3              | 150               | 148                 | 98.66      |   | "                             |
| 5              | 155               | 154                 | 99.35      |   | "                             |
| 6              | 328               | 279                 | 85.06      | 87.70, 83.2                               | "                             |
| 7              | 68                | 60                  | 88.23      |   | "                             |
| 8              | 86                | 73                  | 85.20      | 86.29, 83.2                               | "                             |
| 9              | 61                | 57                  | 93.44      |   | "                             |
| 10             | 256               | 170                 | 66.40      | 42.18, 75.00                              | "                             |
| 14             | 80                | 45                  | 56.25      |   | "                             |
| 17             | 180               | 74                  | 41.11      |   | mainly collapsed              |
| 19             | 493               | 221                 | 44.82      | 22.14, 53.82                              | "                             |
| 21             | 66                | 33                  | 50.00      |   | "                             |
| 26             | 28                | 15                  | 54.28      |   |                               |
| 27             | 328               | 80                  | 24.39      |   | Quite a few collapsed         |
| 33             | 93                | 14                  | 15.75      |   | Batch J <sub>9</sub> 25881/80 |
| 36             | 67                | 7                   | 10.44      |   | Batch J <sub>9</sub> 25881/80 |
| 40             | 170               | 1                   | 5.88       |   |                               |

Using  $\chi^2$  test to test for significant differences between the proportion surviving in each week  $\chi^2$  value = 465.90 which is very significant.

$$P < 0.001$$

Table 4

Percentage survival of *Aedes aegypti* eggs stored for long durations at a Relative humidity of 60%.

| Duration Weeks | Total No. of Eggs | Total No. of Larvae | % Survival | Percentage survival of individual batches. | Description/Remarks                                      |
|----------------|-------------------|---------------------|------------|--|--|
| 1              | 32                | 31                  | 96.87      |  | Fresh  |
| 2              | 60                | 52                  | 86.66      |  | "  |
| 3              | 160               | 147                 | 91.87      | 96.77,<br>88.7                             | "  |
| 4              | 46                | 39                  | 84.78      |  | "  |
| 5              | 186               | 145                 | 77.95      | 85.00, 43.18<br>91.46                      | Most looked fresh yet second batch had very few hatching |
| 6              | 153               | 96                  | 64.15      | 87.5, 26.04<br>75.60                       |  |
| 7              | 191               | 113                 | 59.16      | 39.23, 78.53,<br>93.10                     |  |
| 8              | 58                | 59                  | 50.00      | 50.00, 50.00                               | Some looked collapsed                                    |
| 10             | 130               | 73                  | 56.15      | 25.6, 69.2                                 | "  |
| 12             | 354               | 278                 | 78.53      | 65.2, 81.91<br>82.01                       | "  |
| 14             | 111               | 77                  | 69.36      |  | "  |
| 15             | 125               | 74                  | 59.20      |  | Collapsed  |
| 19             | 156               | 115                 | 73.71      |  | Batch J <sub>9</sub> 25881/60                            |
| 20             | 81                | 53                  | 65.43      | 69.0, 57.90                                |  |
| 25             | 94                | 45                  | 47.87      | 62.96, 27.5                                | Collapsed  |
| 29             | 117               | 10                  | 8.54       | 12.19, 6.73                                | "  |
| 33             |                   |                     | 4.30       |  |  |

Table 5

Percentage survival of *Aedes aegypti* eggs exposed to a 40% Relative humidity over a period of time.

| Duration Weeks | Total No. of Eggs | Total No. of Larvae | % Survival | Percentage survival of individual batches | Description/Remarks                      |
|----------------|-------------------|---------------------|------------|---|--|
| 1              | 29                | 29                  | 100.00     | 82.3, 70.60                               | Still fresh                              |
| 2              | 64                | 49                  | 76.60      | 82.3, 70.60                               | "  |
| 3              | 72                | 54                  | 75.00      |   | "  |
| 4              | 135               | 103                 | 76.29      | 51.11, 88.88                              | "  |
| 6              | 38                | 28                  | 76.66      |   | "  |
| 9              | 80                | 48                  | 60.70      | 45.45, 65.51                              | A few looked collapsed                   |
| 12             | 89                | 49                  | 55.32      | 37.7, 68.0                                | "  |
| 14             | 269               | 199                 | 73.97      |   | Eggs of batch<br>J <sub>9</sub> 25881/40 |
| 15             | 143               | 45                  | 31.46      | 29.68, 32.91                              | Most had collapsed                       |
| 19             | 137               | 39                  | 28.46      |   | "  |
| 20             | 92                | 13                  | 14.13      |   | "  |
| 26             | 452               | 56                  | 12.38      | 12.4, 11.6<br>13.2                        | Eggs of batch<br>J <sub>9</sub> 25881/40 |
| 27             | 67                | 2                   | 2.91       |   |  |

$\chi^2$  test value = 409.81

P < 0.001

Table 6

Percentage survival of Aedes aegypti eggs stored at  
20% Relative humidity

| Duration Weeks | Total No. of Eggs on filter Paper | Total No. of Larvae that Emerged | % Survival | Percentage survival of individual batches. | Description/ Remarks   |
|----------------|-----------------------------------|----------------------------------|------------|--|--|
| 1              | 111                               | 76                               | 68.46      | 64.7, 72.0                                 | Fresh and collapsed eggs   |
| 2              | 65                                | 46                               | 70.76      | 70.76                                      | "  |
| 4              | 121                               | 75                               | 62.00      |  | "  |
| 5              | 32                                | 21                               | 65.00      |  | "  |
| 6              | 164                               | 58                               | 35.35      | 23.25, 38.46, 41.8                         | Most of the eggs looked collapsed  |
| 8              | 55                                | 10                               | 18.18      | 26.66, 9.09                                | "  |
| 10             | 61                                | 5                                | 8.19       |  | "  |
| 13             | 196                               | 3                                | 1.53       | 1.58, 1.44                                 | All looked collapsed   |
| 14             | 315                               | 8                                | 2.53       |  | These eggs belonged to a particular egg batch labelled J <sub>9</sub> 25881/20 |

$\chi^2$  test value = 621.38

P < 0.001

value significant

Table 7

Observation on the effects of exposure to various temperature regimes on larvae and pupae maintained for different time intervals

| Temperature | Exposure Time | No. of larvae or pupa experimented with | Observations   |
|-------------|---------------|---|--|
| 40°C        | 60mins        | 50<br>1st instars                       | All appeared weak after 30 mins. At the end of the experimental time most appeared dead. After 24hrs. only 1 alive   |
|             |               | 40<br>4th instars                       | Movements were shown during the experimental period. After 60 mins, 2 had died, 2 pupated immediately the rest were alive.   |
|             |               | 20 pupae                                | Show movements observed during the experimental period. After 60 mins, 1 was dead. After 24 hrs. 2 died whilst the adults were trying to emerge, 17 adults emerged successfully. |
| 45°C        | 2mins         | 50<br>1st instars                       | Initially weak, some appeared dead. After 24hrs. 2 were dead and the others had all moulted.   |
|             |               | 40<br>4th instars                       | Slower movements initially. After 24hrs all alive 4 had pupated.   |
|             |               | 20 pupae                                | All alive after 24hrs. Later 17 adults emerged successfully.   |

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|             |               | 20 pupae                                | Show movements observed during the experimental period. After 60 mins, 1 was dead. After 24 hrs. 2 died whilst the adults were trying to emerge, 17 adults emerged successfully. |
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|             |               | 40<br>4th instars                       | Slower movements initially. After 24hrs all alive 4 had pupated.   |
|             |               | 20 pupae                                | All alive after 24hrs. Later 17 adults emerged successfully.   |
|             |               | 20                                      | After  |

Table 7 (Cont'd.)

| Temperature | Exposure Time | No. of larvae of pupae used in experiment | Observations   |
|-------------|---------------|---|--|
| 45°C        | 10mins.       | 20 pupae                                  | 2 looked moribund after exposure time and 18 appeared dead. After 24hrs. 4 were alive and adults emerged successfully. |
| 48°C        | 2mins.        | 20 3rd ins instars                        | Still after the experiment. All remained dead after 24 hours.  |
|             |               | 20 4th instars                            | Moving feebly at the end of the experiment. After 24hrs. all dead.   |
|             |               | 20 pupae                                  | Moving after experiment. After 24 hours 12 were alive but 2 adults died on trying to emerge.                           |
|             | 3 mins        | 20 4th instars                            | Motionless at the end of experiment. Remained dead after 24 hours.   |
|             |               | 20 pupae                                  | Most motionless a few twitching. After 24 hours 9 were alive 1 died as adult was emerging.                             |
| 50°C        | 2 mins.       | 50 1st instars                            | Looked dead. After 24 hours all dead.  |
|             |               | 40 4th instars                            | Initially they appeared moribund. After 24 hours - all dead.   |
|             |               | 20 pupae                                  | All appeared dead initially After 24 hours 10 were alive, move slow and they   |

percentage of older larvae and pupae will survive.

At 50°C a 2 minute exposure of pupae did not kill them but anything longer than that will. No larvae can stand this temperature no matter how short the time duration.

### 3.4 DISCUSSION

#### 3.4.1 Eggs

Aedes aegypti eggs kept moist for at least between 48 - 60 hours after hatching (see Plate 4.) retain their shape and their viability even if exposed to harsh environmental conditions for example 20% R.H. for a short period (1½ months). However, after long periods of exposure varying degrees of collapse were observed. This is due to a depletion of stored material or a weakening in the protectiveness of the shell.

The average number of eggs laid per female in these experiments appears to be low as results obtained by Christophers (1960) are as follows:-

| No. of eggs<br>per batch...    | 80-9 | 90-9 | 100-9 | 110-9 | 120-9 |
|--------------------------------|------|------|-------|-------|-------|
| No. of females<br>observed.... | 2    | 2    | 4     | 14    | 8     |

Fewer eggs laid in this present observation are probably a result of unfavourable experimental conditions. Thus the females must have been under some kind of stress. The oviposition sites may not have been favourable as well.

#### 3.4.1.1 Resistant properties

The dormancy period of eggs under storage until an appropriate hatching stimulus is obtained was termed 2nd diapause by Christophers (1960), but this term is no longer used. Successful diapause is dependant on the formation of the primary larva whilst in the egg and if embryonic development does not occur and the eggs do not contain fully developed larvae they are unable to withstand desiccation.

To be able to withstand adverse environmental situations eggs should be exposed for some time to an amount of moisture immediately after hatching. Eggs that are not exposed to the minimum number of hours are invariably rendered inviable. Various names have been given to this critical period for example, Conditioning (Shannon and Putnam 1934), Maturation (Buxton and Hopkins 1927), and Incubation period (Christophers 1960). Bacot (1917) states that eggs are useless if not subjected to the incubation period which MacGregor (1916) gives the following values for this critical incubation time

based on results of experiments he carried out on drying of eggs after oviposition:-

|   |     |     |     |    |    |    |    |    |    |
|---|-----|-----|-----|----|----|----|----|----|----|
| Maximum time left on H <sub>2</sub> O (hours) | 15  | 20  | 25  | 37 | 43 | 48 | 60 | 65 | 70 |
| % collapse after 12 hours drying              | 100 | 100 | 100 | 62 | 28 | 2  | 0  | 0  | 0  |

Christophers (1960) states that the eggs absorbs water for at least 6 hours and water proofing properties of eggs begin developing after 24 hours and as such duly protects it from desiccation. The primary larva<sup>e</sup> has remarkable powers to lie dormant until submerged and even then repeated stimuli may be needed to break diapause. Some eggs fail to hatch after repeated soakings and these are termed residual eggs. It appears that a few residual eggs must have been present in this study because certain egg batches that were expected to give high yields did not even hatch after several soakings although some of the eggs did look normal. This was encountered most with an atmospheric relative humidity of 40 per cent. These abnormalities and low percentages recorded could be attributed to the low viability of the eggs themselves, insufficient conditioning or errors occurring during counting of larvae and pupae. Some of these eggs are probab<sup>l</sup>y the type which do not completely collapse but need more than 3 soakings

to stimulate hatching. Many species of Aedes are capable of arresting development at the egg stage and still retain their viability once the embryonic development and conditioning periods are over. Service (1965) reports of the four commonest species of this genus Ae. aegypti, Ae. luteocephalus, Ae. unilineatus and Ae. stokesi hatching after variable lengths of diapause in the field. In some cases it required 6 soakings to get certain egg batches of Ae. aegypti and Ae. luteocephalus to hatch although majority hatched after the 3rd soaking. Fielding (1919) reported that certain eggs of Ae. aegypti had to be soaked and dried 13 times before the larvae emerged.

Clements (1963) stresses that eggs vary in the strength of hatching stimulus which they required in the field and the strength of these hatching stimuli factors which are mechanical agitation, anaerobiosis (Gillet 1955a) and a fall in temperature (Fielding 1919) may also be responsible for the spread in hatching.

The hatching stimulus used in these experiments was Cerelac a Nestle's baby food product which comprises mainly of corn thus providing the organic matter needed for the eggs to hatch. Hatching occurs less readily in clean water than in media rich in organic matter such as infusion or

slightly polluted water (anaerobiasis). Bacot (1917) recorded that eggs could stay viable whilst totally submerged for as long as 5-7 months without hatching if the organic content was low. The addition of foul contaminated water caused a high percentage to hatch in a very short period. Ideally these Relative humidity experiments should have been conducted at higher temperature for example 30°C. Temperatures recorded in these study areas range from 22°C to 37°C and therefore since we know what happens at 20°C it is possible to estimate what would happen at other temperatures.

From data obtained it appears that even though eggs stored under 80% R.H. may be viable for 10 months, after the first 5 months higher percentage hatch was recorded from a 60% R.H. (69.36%) atmosphere than at 80% (50.00%). These results are similar and the difference could be due to laboratory technicalities or the genetic constitution of eggs chosen for that length of desiccation. From methods used conclusions that can be drawn are that Relative humidities above 60% support viability of Aedes aegypti eggs for long periods. Relative humidities 20% and 40% show results that are reasonable in that these 2 regimes represent severe drought conditions and thus the low survival yields after

short periods of duration are to be expected. The required Relative humidity for optimum survival of eggs appears to be 60% and above.

Some authorities however reported that eggs of most Aedes sp. will not survive below 70% R.H. (Clements 1963) and that a two day exposure to 53-58% R.H. killed almost all the eggs of Aedes rubithorax but only 5% of closely related Ae. rupestris (Drobrotworsky 1958). Pillai (1962) however reports that Ae. achoratatus survives 10-15 weeks at 53% R.H. There were two occasions of electricity failure during the experimental period. The atmosphere in the desiccators did not take too long to return to normal and it is assumed that this unexpected event did not affect the eggs too much.

Naturally laboratory experiments cannot totally approach conditions in the field and they must be interpreted with care. In most tropical countries the dry season often lasts several months and eggs of these Aedes species can only survive if they can tolerate high degrees of desiccation for prolonged periods. In contrast eggs of Aedes species that live in temperate climates are not exposed to such periods of desiccation and are less resistant to desiccation. These described experiments therefore prove that once eggs are properly

conditioned extreme environmental conditions are tolerated.

#### 3.4.2 Larvae: High Temperatures

Macfie's (1920) stated 46°C as the highest temperature larvae and pupae can tolerate. This study shows that pupae may survive if exposed for brief periods to temperatures of 50°C (2mins.). Service's (1970) findings on Ae. vittatus shows that the pupae can only stand 46°C for 10 minutes. Boormann (1961) however stated that neither larvae or pupae of Ae. vittatus could tolerate temperature of 45°C. Christophers (1960) recorded complete mortality of Ae. aegypti pupae after 3 minutes at 48°C. Bar Zeev (1958) expresses his results as LT50s and he states that the order of resistance to high temperatures are eggs, young pupae, old pupae, larvae and adults. The young pupae he said are protected by a hard outer covering. The highest temperature that he worked with was 45°C. This knowledge is important because at certain times of the year water in small habitats e.g. rock pools (and tin cans) may get heated up to temperatures of about 43°C (Service 1970). Mackerras and Lemerle (1949) record heated water at temperatures of 40°C and they also found that Ae. punctulatus (Donnitz) completed its development at 40°C in the field but in the laboratory died at 37°C.

62.

Finally we may stress that Aedes aegypti populations will always be difficult to wipe out completely because the eggs, larvae and pupae are very tolerant and appear to withstand the most extreme environmental conditions. The fact that not all the eggs hatch on the initial soakings is extremely advantageous especially in the habitats that the eggs are laid in. Since the amount of rainfall varies not all the eggs may hatch since the diapausing eggs will be situated at various heights in these habitats e.g. Tree-holes. This phenomenon will definitely ensure continuity of the species.

3.5 AN INVESTIGATION INTO THE REGULATION OF PRE-IMAGINAL  
AEDES AEGYPTI POPULATIONS

3.5.1 Introduction

Causes of mortality in mosquitoes have been attributed to starvation, competition for food and space, adverse climatic conditions, pathogens and parasites, occasionally it seems that the greatest single contributing factor determining population size is predation (Service 1976). In villages where peridomestic breeding is encouraged predators are not always found in large enough numbers and it was suggested that factors like food and overcrowding (Subra 1977) would be the source of population regulation. An investigation of this nature to point out why populations never exceeded epidemic proportions in our areas of study and to find out which regulatory factor plays the most significant role would therefore be useful for control measures.

3.5.1.1 Competition for Food and Space

Christophers (1960) conducted experiments on larvae reared in the absence of food. He observed that larval developmental period was increased and the few larvae that matured were small.

Overcrowding also has similar effects. Although it is difficult to determine the limit, it will be possible to obtain data as a source of reference because if culture conditions are good a large number of larvae can exist together. Subra (1977) carried out researches on Ae. aegypti to find out how food and large populations affected subsequent population densities. He concluded that although overcrowding was an important regulating factor in the Kenyan villages he worked in, food was the main control factor.

#### 3.5.1.2 Predation by Various Insect Larval Stages

Several arthropods have been listed as being predators of Ae. aegypti and these include larger mosquito species Toxorhynchites brevipalpis conradti Grünberg (Muspratt 1951; Christophers 1960; Corbet 1962; Laird 1967; Trpis 1972; 1973; Lounibos 1979); Culex (Lutzia) tigripes Grandpré and Charmoy (Haddow 1942; Jackson 1953; Christophers 1960) and certain Odonata nymphs (Gordon 1922; Christophers 1960; Corbet 1962; Laird 1967) and a host of aquatic beetles.

The predatory larvae of Tox. brevipalpis have been a source of interest as it has been attempted several times to establish them in large colonies to act as biological

control agents for medicinally important mosquitoes (Paine 1934; Gerberg and Visser 1978). The adults do not feed on blood and are thus advantageous. They breed in tree-holes and bamboo stems in preference to peridomestic containers. Detailed work has been carried out in East Africa by Lounibos (1979), Corbet (1962, and Trpis (1972, 1973) on their biology and ecology. In West Africa they have been reported in Nigeria (Service 1963) and in Ghana (Ingram and Macfie 1924) but little is known of their effectiveness.

Jackson (1953) working in Nigeria discusses the feeding behaviour of Culex tigripes and established the fact that Ae. aegypti was the most preferred prey species in comparison to other Culex and Anopheline species.

Although little literature exists on Odonata nymphs predated on Ae. aegypti they are well known to predate on other organisms (Corbet 1962; Jenkins 1964). Johnson et al. (1975) and Thompson (1975) give detailed accounts of their predation on Daphnia sp. and Service (1970) on Ae. vittatus. During sampling in the survey areas it was observed that mosquito larvae were seldom caught in large cement water holding containers and this was due to the presence of Odonata nymphs breeding in them.

66.

The efficiency of these three predating larvae will be assessed in the laboratory and field to ascertain the role each can play in the maintenance of Ae. aegypti populations.

### 3.6 MATERIALS AND METHODS

#### 3.6.1 Competition for food and space

To investigate the effects of food and overcrowding on Ae. aegypti populations 4 sets of experiments were conducted. In Series A, there was a constant amount of food supplied to different numbers of larvae (20, 40, 60, 80, 100). In Series B, there was a constant number of larvae (20) but differing amounts of food. Series C, was to investigate the effect of larval numbers on duration of larval development. Various numbers of larvae (10, 20, 30, 40, 50, 60, 70, 80, 90, 100) were put into 50ml of water; enough food was given according to the numbers of larvae in the beaker. Series D comprised of an experiment in the yard by the laboratory. In this experiment nine earthenware pots were seeded with different numbers of larvae (100, 300 and 600) which were given the same amount of food. This was an attempt to attain field conditions. The pots were covered with a gauze material to prevent further oviposition or any predation and the water was agitated periodically.

67.

For experiments A, B, and C, 1st instar larvae were used and were held in 50ml beakers. Food given was Cerelac baby food.

Two controls were set up for series B. Control A, had first instar larvae and were starved throughout the experiment. In control B, the larvae were given only food and 'no water' that is a highly concentrated food mixture.

Since minute quantities of food were used, errors in weight were avoided by giving the quantities of food in known volumes. The stock solution was made by dissolving 1gm of food in 100ml of tap water. Therefore in series A, for every beaker there was 10ml of food solution and 40ml of water.

For series B, beaker 1) 10ml food solution 40ml water (10f /40w)  
" 2) 20ml " " 30ml " (20f /30w)  
" 3) 30ml " " 20ml " (30f /20w)  
" 4) 40ml " " 10ml " (40f /10w)  
" 5) 50ml " " 0ml " (50f / 0w)

For series D larvae were reared in 4 litres of water to which 1.0gm of food had been added. Where possible experiments were replicated twice.

In each case the total numbers of larvae that reached the pupal stage <sup>and</sup> the duration was recorded.

### 3.6.2 Predation

Predators to be used for the experiment were caught in the field. Most of the Tox. brevipalpis were either caught in earthenware pots or in tree-holes and tin cans left around for this purpose. Culex tigripes were collected mainly from domestic pots and the Odonata nymphs (Brachythemis leucostica) in large cement receptacles. Since it was difficult to determine the age of some of these arthropods it was desirable that the earliest instars were caught and brought to the laboratory. The predators were reared individually in a 100ml of water and it was noticed that just before a moult the larvae appeared sluggish and were therefore in an appropriate stage to be introduced to the experiments. Instars of mosquito larvae were determined by examining the head capsule. In the case of the Odonata nymphs the whole excuviae were examined.

The prey to be used in these experiments were maintained in large glass containers at room temperature (27<sup>0</sup>C) and fed on baby food. A minimum of 5 replicates and sometimes as many as 10 were used. The number of prey eaten by the various predators of different sizes over a range of prey densities within a 24 hour period was calculated.

69.

The controls were set up because as pointed out by Lounibos (1979) at certain densities prey died due to causes other than predation and some prey corpses were scavenged and eaten by other prey larvae.

The food preference of the predators to different species of mosquitoes larvae was tested by exposing various species C. decens and C. horridus and Ae. aegypti to these predators over a period of 24 hours and the numbers eaten were recorded.

Where possible the attack coefficient 'a' and the handling time 'T<sub>h</sub>' were estimated. To do this Roger's (1972) equation was used as follows:-

$$N_a = N (1 - e^{-a(T - N_a T_h)})$$

where  $N_a$  = no. of prey eaten

$T$  = total time prey are exposed to predation

$N$  = prey density

The use of equation was necessary because results are affected to some extent by prey exploitation. These two parameters can however be estimated by a graphical method using the linear regression formula:-

$$\log \left( \frac{N - N_a}{N} \right) = a T_h N_a - a T$$

Functional responses of the different predator instars of Tox.brevipalpis to the different instars of Ae. aegypti can

70.

be fitted in after the graphs of numbers eaten against prey density have been plotted and in such a situation the appropriate estimates of 'a' ie. the attack coefficient and the Handling time ' $T_h$ ' can be estimated from an iterative Newton - Raphson technique (Sutton 1954).

### 3.7 RESULTS

#### 3.7.1 Competition for food and space

Results obtained are shown below in Tables 8 - 11. Table 8 and 11 show that varying numbers of larvae feeding on the same amount of food cause prolonged developmental time at high densities. This is probably because the weaker individuals are oppressed and therefore have less to eat. The rate of mortality also increases.

Table 9 shows that a high concentration of food has lethal effects as after 3 days there were no survivors for treatment 0w/50f. In contrast when there was no water at all, treatment 50w/0f some of the larvae were able to live for 8 days and the last one died after 17 days in the third instar. Larvae in treatment 50w/1f all turned out to be minute undernourished adults. Treatment 40w/10f seemed adequate as all the 20 larvae pupated into healthy adults, but the

Table 8 Series A

Rate of maturation of different densities of Ae. aegypti larvae fed on a constant amount of food.

| No. of the<br>larvae | No. of pupae observed after days shown below |    |    |    |    |    |    |    |    |    | Total No. of pupae<br>formed (% in parentheses) |
|----------------------|--|----|----|----|----|----|----|----|----|----|---|
|                      | Days   | 5  | 6  | 7  | 8  | 10 | 11 | 12 | 13 | 14 |   |
| 1                    | 11   | 7  | 2  |    |    |    |    |    |    |    | 20 (100.00)                                     |
| 2                    | 6  | 12 | 22 |    |    |    |    |    |    |    | 40 (100.00)                                     |
| 3                    | 1  | 17 | 34 | 2  | 1  |    |    |    |    |    | 55 (91.66)                                      |
| 4                    | -  | 2  | 25 | 20 | 13 | 1  | 9  | 2  |    |    | 72 (90.00)                                      |
| 5                    | -  | 1  | 6  | 7  | 23 | 3  | 33 | 6  |    |    | 79 (79.00)                                      |

Table 9 Series B  
 University of Ghana <http://ugspace.ug.edu.gh>

Observation on the effect of different quantities of food on the length of maturation on a specific number (20) of Ae. aegypti larvae.

| Numbers of Pupae Observed on the days shown below |                |   |              |               |               |               |                 | Total of Pupae Formed |
|---|----------------|---|--------------|---------------|---------------|---------------|-----------------|-----------------------|
| 2   | 3              | 5 | 6            | 7             | 8             | 15            | 17              |                       |
| 10 larvae dead                                    | 10 larvae dead |   |              |               |               |               |                 | 0                     |
|   |                | 5 | 5            | 8             | 2             |               |                 | 20                    |
|   |                |   | 11           | 5             | 4             |               |                 | 20                    |
|   |                | 1 | 6            | 7             | 6             |               |                 | 20                    |
|   |                |   | 3            | 5             | 12            |               |                 | 20                    |
|   |                |   | 7            | 9             | 2             |               |                 | 18                    |
|   |                |   | 1 dead larva | 5 dead larvae | 7 dead larvae | 6 dead larvae | last larva died | 0                     |

Quantities of food given to the larvae for example 10w/40f means 10 mls of water was added to 40mls of the solution etc. etc.

Table 10 Series C

University of Ghana <http://ugspace.ug.edu.gh>  
 Observations on the effect of high densities of *Ae. aegypti* larvae kept under similar conditions on the length of the life cycle

| No. of pupae formed<br>(% in brackets) | No. of Adults<br>(% in brackets) | Duration*<br>Days   | %<br>Mortality | Remarks  |
|--|----------------------------------|---------------------|----------------|--|
| 10.00<br>(100.00)                      | 10.00<br>(100.00)                | L - 5<br>P - 3      | 0              | Larvae and pupae formed were all healthy and large.            |
| 20.00<br>(100.00)                      | 18.33<br>(91.65)                 | L - 6-7<br>P - 3    | 30.00          | -  |
| 28.00<br>(93.33)                       | 26.33<br>(87.76)                 | L - 6-9<br>P - 2-3  | 12.23          | Over 50% of the larvae developed into pupae by day 8           |
| 37.00<br>(92.50)                       | 35.00<br>(87.50)                 | L - 7-10<br>P - 2-3 | 12.50          | 65% pupae has been formed by day 9                             |
| 48.00<br>(96.00)                       | 47.66<br>(95.32)                 | L - 7-10<br>P - 2-3 | 5.00           | -  |
| 47.00<br>(78.33)                       | 45.00<br>(75.00)                 | L - 6-11<br>P - 2-3 | 25.00          | Majority of pupae formed after day 8, there was high mortality |

| Initial No. of larvae | No. of pupae formed<br>(% in brackets) | No. of Adults<br>(% in brackets) | Duration of<br>Days | Mortality | Remarks   |
|-----------------------|--|----------------------------------|---------------------|-----------|---|
| 77                    | 50.00<br>(64.92)                       | 57.66<br>(74.63)                 | L - 7-12<br>P - 2-3 | 30.50     | Highest mortality recorded here   |
| 80                    | 53.33<br>(66.66)                       | 61.00<br>(76.25)                 | L - 6-11<br>P - 2-3 | 23.50     | Pupae observed on day 5 and linked pupae  |
| 90                    | 77.78<br>(86.66)                       | 72.00<br>(80.00)                 | L - 6-13<br>P - 2-2 | 20.50     | High pupae mortality and developmental time. Most larvae pupated day 8.   |
| 200                   | 76.50<br>(76.50)                       | 74.33<br>(74.33)                 | L - 6-15<br>P - 2-2 | 25.67     | A few pupae were formed on day 8 (25.33) the rest were formed at about equal number each day till day 15. Longest life cycle period observed here. Adults were also of a diminished size. |

L - Larval duration

P - Pupal duration

Table 11 Series D

Observations on the rate of maturation and the effect of density on Ae. aegypti larvae kept in earthenware pots under field conditions.

| Expt | Eggs | 1st   | 2nd   | 3rd   | 4th   | Pupa  | Adults | Duration* |
|------|------|-------|-------|-------|-------|-------|--------|-----------|
| 1    | 100  | 100   | 100   | 100   | 100   | 100   | 100    | 9         |
|      | 100  | 98    | 98    | 98    | 96    | 96    | 93     | 10        |
|      | 100  | 100   | 100   | 97    | 97    | 97    | 94     | 10        |
| Mean | 100  | 99.3  | 99.3  | 98.3  | 97.6  | 97.6  | 95.6   | 9.66      |
| 2    | 300  | 287   | 260   | 254   | 240   | 236   | 230    | 10        |
|      | 300  | 290   | 278   | 273   | 264   | 260   | 251    | 11        |
|      | 300  | 300   | 291   | 281   | 265   | 255   | 241    | 13        |
| Mean | 300  | 292.3 | 276.3 | 266.0 | 256.3 | 250.3 | 240.6  | 11.33     |
| 3    | 600  | 580   | 561   | 543   | 530   | 498   | 480    | 12        |
|      | 600  | 600   | 587   | 564   | 553   | 531   | 520    | 14        |
|      | 600  | 593   | 569   | 531   | 510   | 510   | 477    | 13        |
| Mean | 600  | 591   | 572.3 | 546.0 | 531   | 507   | 489    | 13.00     |

\*Duration here is the time taken for 50% of the larvae to complete the life cycle and emerge as adults.

larval duration was delayed for several days. If food concentrations are not lethal for a given density the more food available the faster the developmental rate.

Overcrowding (Table 10) has the effect of prolonging pre-imaginal duration. Mortalities are also greater at these high densities.

### 3.7.2 Predation

Tables 12-14 summarise the efficiency of the three predators on Ae. aegypti. The efficiency of the different predatory stages of Tox. brevipalpis have been arranged into 2 main tables for clarity as numbers of prey eaten by 1st and 2nd predator instars are similar and likewise 3rd and 4th instars of the predator feed on approximately the same number of prey. At high densities the numbers of 1st and 2nd prey instars eaten were usually high most probably due to the greater number of encounters. For the older prey instars at high densities a smaller proportion of prey are eaten and although the progression is not so marked, it appears that more time is required for eating one large prey as compared to a small young prey.

77.

Table 12a

Numbers of prey eaten at different densities by 1st and 2nd instars of Tox. brevipalpis, within 24 hours.

| Prey<br>Density | No. of Prey (Instar indicated below) eaten $\pm$ S.E. |                  |                 |                 |
|-----------------|---|------------------|-----------------|-----------------|
|                 | 1st   | 2nd              | 3rd             | 4th             |
| 5               | 5.0   | 5.0              | 4.71 $\pm$ 0.21 | 4.33 $\pm$ 0.31 |
| 10              | 8.0 $\pm$ 0.02  | 8.51 $\pm$ 0.36  | 7.74 $\pm$ 0.81 | 6.0 $\pm$ 0.27  |
| 15              | 10.0 $\pm$ 0.43                                       | 10.00 $\pm$ 0.61 | 6.3 $\pm$ 1.42  | 7.00 $\pm$ 0.45 |
| 20              | 14.5 $\pm$ 0.41                                       | 12.00 $\pm$ 0.07 | 9.7 $\pm$ 0.86  | 7.82 $\pm$ 0.82 |
| 25              | 17.5 $\pm$ 0.51                                       | 10.3 $\pm$ 0.13  | 8.2 $\pm$ 0.53  | 8.0 $\pm$ 0.53  |

FIG. 7 EFFECT OF PREY DENSITY ON NUMBERS OF PREY EATEN BY  
1st AND 2nd INSTAR *Tox brevivalpis*

KEY

- ▲ 1st INSTAR
- 2nd INSTAR
- + 3rd INSTAR
- 4th INSTAR
- CALCULATED FUNCTIONAL RESPONSE (instar indicated)

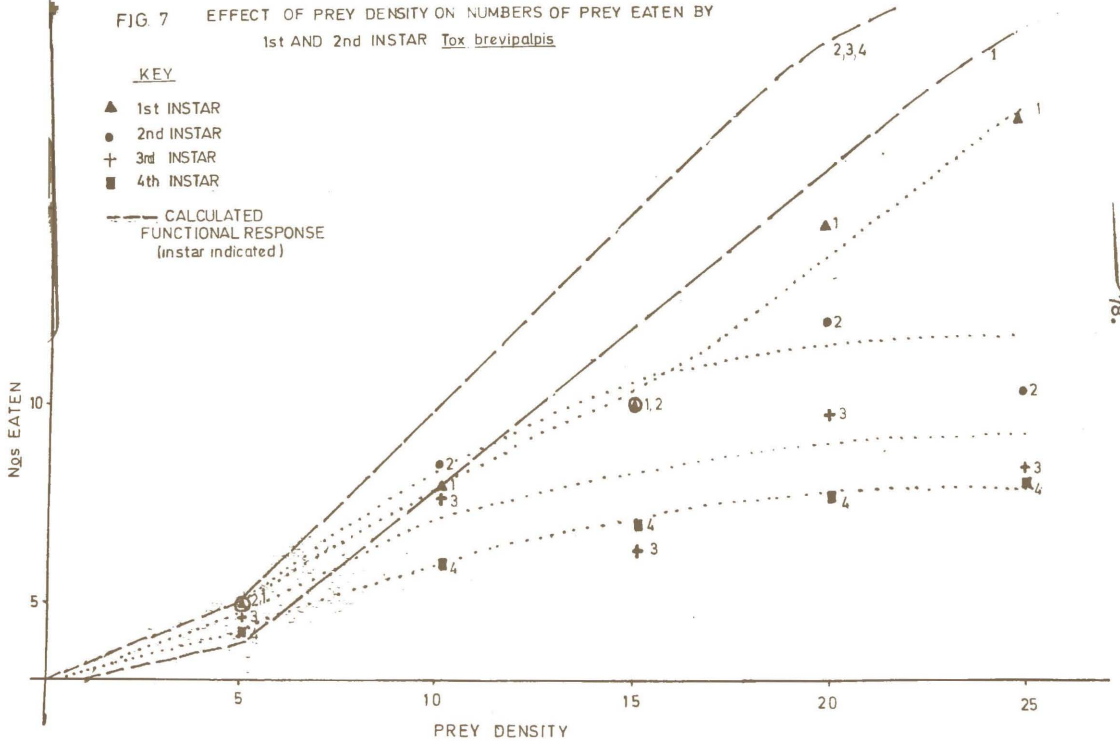


Table 12b

Numbers of prey eaten at different densities of the prey by 3rd and 4th instars of Tox. brevivalpis within 24 hours.

| Prey Density | No. of Prey (Instars indicated below) eaten $\pm$ S.E. |                 |                 |                 |
|--------------|--|-----------------|-----------------|-----------------|
|              | 1st  | 2nd             | 3rd             | 4th             |
| 5            | 5.0  | 5.0             | 5.0             | 5.0             |
| 10           | 10.0   | 10.0            | 9.8 $\pm$ 0.61  | 9.6 $\pm$ 0.02  |
| 15           | 15.0   | 13.3 $\pm$ 0.08 | 9.0 $\pm$ 0.43  | 7.8 $\pm$ 0.10  |
| 20           | 20.0   | 14.5 $\pm$ 0.12 | 15.5 $\pm$ 0.51 | 12.0 $\pm$ 0.29 |
| 25           | 18.9 $\pm$ 0.16  | 17.1 $\pm$ 0.32 | 13.2 $\pm$ 0.31 | 14.2 $\pm$ 0.56 |
| 30           | 22.7 $\pm$ 0.09  | 17.3 $\pm$ 0.42 | 16.4 $\pm$ 0.21 | 15.3 $\pm$ 0.91 |
| 40           | 23.7 $\pm$ 0.20  | 19.2 $\pm$ 0.51 | 14.5 $\pm$ 0.08 | 14.0 $\pm$ 1.56 |

FIG 8 EFFECT OF PREY DENSITY ON NUMBERS OF PREY EATEN BY  
3rd AND 4th INSTAR *Tox brevipedis*

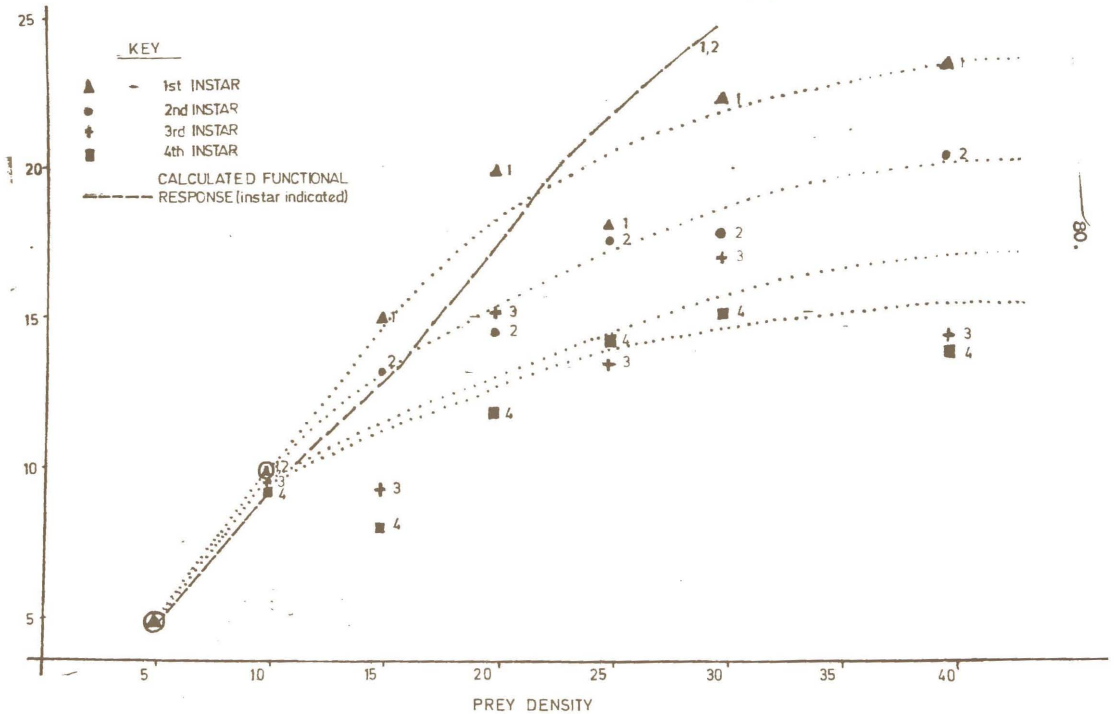


Table 13

Numbers of Ae. aegypti eaten by Culex (L) tigripes

| Predator<br>Instar | No. of prey eaten at the following densities (3rd and 4th prey Instars) |            |             |             |            |             |
|--------------------|---|------------|-------------|-------------|------------|-------------|
|                    | 5   | 10         | 15          | 20          | 25         | 30          |
| 2nd                | 3.1 ±   | 4.2 ± 0.61 | 5.3 ± 1.61  | -           | -          | -           |
| 3rd                | 5.0   | 9.1 ± 0.31 | 12.1 ± 0.83 | 16.0 ± 0.31 | 20.0 ± 0.8 | -           |
| 4th                | 5.0   | 10.0       | 13.5 ± 0.91 | 18.4 ± 0.01 | 23.7 ± 0.2 | 25.8 ± 0.15 |

Table 14

Numbers of Ae. aegypti eaten by Brachythermis leucostica nymphs

| Predator<br>Instar | No. of prey eaten at the indicated densities (Instars are in parenthesis) |                 |                    |                 |                    |                     |                    |
|--------------------|---|-----------------|--------------------|-----------------|--------------------|---------------------|--------------------|
|                    | 5   | 10              | 15                 | 20              | 30                 | 40                  | 60                 |
| 2nd                | 5.0 (4)   | 7.90 ± 0.31 (4) |                    |                 |                    |                     |                    |
| 3rd                | 5.0 (4)   | 9.9 ± 0.25 (4)  | 14.1 ± 0.01<br>(4) | 17.9 ± 0.5 (4)  | -                  | -                   | -                  |
| 4th                | 5.0 (4)   | 10.0 (4)        | 15.0 (4)           | 18.1 ± 0.5 (4)  | 30.0 (2)           | -                   | 60.0 (2)           |
| 5th                | 5.0 (4)   | 10.0 (4)        | 15.0 (4)           | 18.0 ± 0.32 (4) | -                  | 36.21 ± 0.52<br>(3) | -                  |
| 6th                | 5.0 (4)   | 10.0 (4)        | 15.0 (3)           | 18.1 ± 0.71 (4) | -                  |                     | 58.0 ± 0.02<br>(2) |
| 8th                | 5.0 (4)   | 10.0 (4)        | 15.0               | 18.02 ± 0.2 (4) | 20.0 ± 0.41<br>(3) |                     |                    |

83.

With the 3rd and 4th predator instars large numbers of 1st and 2nd prey instars were eaten. For older prey however, fewer numbers are eaten and at very high densities even less prey are consumed due to the fact that when predators are agitated too much they often eat less or let the prey caught, go. Results have been expressed graphically (see Figs. 5 and 6). The fitted curves describe the data well (where available) but in some case there is a tendency to over estimate numbers eaten at high densities. In some cases computed values of 'a' and 'Th' were too large and no appropriate curve could be fitted. (see appendix 3a).

Not enough Culex sp. could be obtained for the species preference experiments and therefore it was not possible to carry out any systematic analysis. Available data can be seen in Appendix 3 and it shows that whenever Culex horridus or Culex decens were supplied with Ae. aegypti the latter was eaten in larger quantities.

Fourth instar C. tigripes are very efficient predators as they eat larger numbers of Ae. aegypti than Tox brevipalpis in the same time. Their life span is, however, too short to make any great impact on prey numbers as the fourth instar last for only three days and just before it pupates

it hardly eats at all.

Odonata nymphs ate exceptionally large numbers of Ae. aegypti. Although at very high densities only young prey were offered to them the predatory efficiency was very high. Even when fed with fourth instar Ae. aegypti at least 20 could be eaten in a given time. From results it appears that the eating capacity of the older naiads is comparable to the younger ones. Control experiments did not show any evidence of scavenging of dead corpses by other larvae. The experimental prey densities were probably not high enough.

### 3.8 DISCUSSION

Subra (1977) created a situation of overcrowding and varied the amounts of food in already infested village pots. He found out that the addition of larvae does not increase pupal density but rather food does. Oviposition does not play a major role in the regulation of pre-imaginal density. He felt that overcrowding may be important but densities rarely reached this level as water is renewed almost daily and eliminates a part of the population that could contribute to overcrowding. Results of the present study relate closely to Subra's findings especially Series D which was

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conducted in the field. Overcrowding definitely increases the developmental period and thus the larvae are exposed to dangers of predation or of being killed by the emptying, cleaning or filling of pots. Pupae that would contribute to the adult population are not given a chance at all. Starvation creates similar hazards because the larvae are weak, easily preyed upon and the life cycle is greatly increased. But food is normally available through organic debris and it has been shown that larval food requirements are very small. In considering food and overcrowding we may conclude that in areas where peridomestic populations are supported overcrowding is not a very crucial factor as most storage containers are large and food is usually abundant but it could be a limiting factor as sometimes water is supplied by water tankers and some families are very particular and always have their pots covered. Both factors contribute to fewer adults. High density breeding containers always attract the women to change the water. In a feral population overcrowding could be a major regulatory factor as it would lead to increased predation and ultimately fewer adults.

Accurate measurements on the effect of predation by any arthropod on the larvae of Ae. aegypti is very important.

Service (1976) however stresses the fact that laboratory conditions are highly artificial and rarely provide much understanding of the importance of the predator in the field as it is difficult to take account of all the other possible alternative prey. Aquatic insects which have been noted for attacking Ae. aegypti under artificial conditions are not necessarily effective in nature.

Holling (1961) list the factors that affect effective predation as:- (a) prey density, (b) predator density, (c) characters of the environment, (d) characters of the prey, (e) characters of the predator. Another important factor is the time in which the prey and predator are exposed to each other and these were calculated as the handling time (' $T_h$ ') and the attack coefficient (' $a$ ') which are further discussed.

Of the three aquatic predators studied only Tox. bre-palpis has been used extensively and in practical examples. This is because it is harmless to man whilst Lutzia has been reported to suck blood and could perhaps transmit a disease (Jackson 1953). Odonata naiads have never been considered important as most workers group them as bottom feeders and that makes it doubtful if they can reduce Ae. aegypti populations to any appreciable level.

The introduction of Tox. brevipalpis into the Fiji islands by Peine (1934) is an example of an attempt at biological control. They were easily established in the available habitats and multiplied rapidly. The vector was eradicated within a short time and since the predators has nothing else to feed on they died out. Similar findings were obtained by Gerberg and Visser (1978) at Simpson Bay, Carribean islands. In this case infested receptacles were seeded with eggs of the predator based on the extent of infestation and the size of the receptacle. Within a month there were no Ae. aegypti left; again cannibalism was resorted to amongst the predators and consequently prey numbers increased again because of their resistant eggs.

It is unfortunate that the penultimate instars of Odonata naiads were rarely encountered during the experimental period as most of them quickly dived to the bottom and stayed there for long periods. Thus their efficiency could not be assessed. Results show that the younger nymphs are effective and eat everything offered to them. Laboratory experiments conducted by Service (1970) proved the dragonfly nymphs caught in the field to be valueless as efficient predators of Ae. vittatus. Corbet (1962) says

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that they are unlikely to be effective as they are facultative feeders. They would only do well if the only prey available was Ae. aegypti but that would lead to their extinction. Service (1970) observed them to eat  $3.5 \pm 0.2$  third and fourth larvae and  $0.2 \pm 0.2$  pupae within 24 hours. Service (1970) accounted for the significantly lower numbers of pupae eaten by pointing out that dragonfly nymphs normally browse over the mud at the bottom whilst unless unduly disturbed pupae are always at the surface and are less often encountered.

Fourth instars Culex (Lutzia) tigripes eats a little more than 4th instar Tox. brevivalpis for a given density and prey size but the numbers are comparable.

Tox. brevivalpis in previous experiments appears to eat much more than recorded in this present study. Muspratt (1951) and Corbet (1962) have values of daily consumption that are comparable. Tox. brevivalpis has the advantage over Lutzia of being longer lived and more active thereby having a much larger total intake. Calculated values of possible numbers eaten, approached what actually occurred in the laboratory however. The 'a' and 'T<sub>h</sub>' are average values and that probably explains why the random predator equation predicts slightly lower numbers eaten at low dens: t

higher numbers at high densities sometimes.

In nature the difference in the generation times of the predator and prey has many limitations and as pointed out by Johnson et. al. (1975) the predators life span is often too long to respond to short term changes in prey density. Aedes aegypti may be described as an r - selected individuals and the predator Tox. brevipalpis as 'K - selected' and it has been observed that for the effective control of one biological species on another the two should exhibit similar life history strategies (Bedon and Mortimer 1981).

R - selected populations normally live in an environment which is unpredictable in time and the population fluctuates as a result of repeated colonization. Juvenile and adult populations are density dependant. The adults are small and the young ones have a short life span. Most of their energies are devoted into reproduction so that the percentages surviving to adult stage may remain essentially large. K - selected populations in contrast live in an environment that is seasonal and density dependant factors are responsible for checking adult population size. Energies are exerted towards maintenance and growth and a small effort is made on reproduction. K - selected

individuals are larger in size and fewer in numbers. Pianka (1970) feels that no organism is completely r - or K - selected and characters of both types can be observed. Most insects he classified as r - selected. Therefore by the time Tox. brevipalpis have reached stages where predatory abilities are most effective, several generations of the prey would have lived. Aedes aegypti will usually occur in large densities and may be too many for K - type predators to effect adequate control.

The mode of attack is different for all three. Tox. brevipalpis spends a lot of time moving, rarely eating at first contact; C. tigripes remains still moving occasionally but attacks immediately the prey gets into contact with it. Odonata nymphs hunt by remaining entirely stationary and only bite when the prey passes close by. This factor is important when the size of the container increases because for a given density, the efficiency of these predators especially the Odonata and Lutzia larvae will decrease.

It appears more practicable for first instar Tox. brevipalpis to encounter freshly hatched Ae. aegypti than fourth instars of the prey, or first instar Tox. brevipalpis to encounter third and fourth instars of the prey, unless the container is very large and there is a lot of debris

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in it. Most of the previous workers fed their predators with prey of approximately equal size. To obtain a complete view of their efficiency a range of prey sizes were fed to a range of predators.

Present results from this study indicate that fourth instar Tox. brevipalpis feeds on large numbers of first and second prey instars. At a density of 40 1st instars an average 23.7  $\pm$  0.20 (range 21 - 27) prey were eaten. They however ate much lower numbers of the older instars, a maximum of about 15 a day (a range of 8-20). Lounibos (1979) in his study records 20 fourth instars prey consumed on the days of maximum numbers consumed with 24 hours. He went on to establish the fact that fourth instars were preferred to second instars and pupae to fourth instars. This fact points out that predators normally select prey of comparable size.

Corbet (1963) and Garnham et al. (1946) and Muspratt (1961) record values of between 11.3 - 16, third and fourth instars of the prey as being maximum numbers consumed in 24 hours.

An initial slow rate of feeding by fourth instar Tox. brevialpis was observed after periods of starvation and it is known that this is the stage through which this species survives the severest environmental conditions. Only about 3-5 prey larvae were eaten after 10 days of starvation by two fourth instar predators. This is because the predators take <sup>time</sup> to re-adjust again being used to conditions of starvation.

Cannibalism has been reported amongst this predatory species. This actually happens only in extreme conditions (Corbet 1962), but Garnham et.al. (1946) findings indicate that only 2 or 3 predators can co-exist in a tyre at a time. Trpis (1972) reports the presence of 21 in an abandoned car tyre and in this present study 17 predators of different instars were found in one tree-hole. There was evidence of 2 fourth instar predators devouring 5 first and second instars in this study. The destruction of prey, a manifestation of the prepupal stage was also observed and between 20-30 fourth instar larvae or the prey were destroyed in this period. Lounibos (1979) reports that pupation is dependent on body weight of the fourth instar, the critical weight being 26mg.

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Jackson (1953) reports that C. tigripes ate between 28 to 35, 3rd and 4th Ae. aegypti within three days. In this present study 24 out of 25, 4th instar prey were eaten by one predator in 24 hours. Lutzia were also observed to prefer Aedes sp. to Culex sp. Jackson (1953) explains this as due to the fact that Culex sp. move very fast but are less spontaneous by mobile prey tests as compared to Ae. aegypti.

There was no available literature to compare with results obtained for Odonata nymphs. Since most of the replicates showed comparable data it appears that Odonata naiads have a great appetite for Ae. aegypti and this increases with starvation. They also feed on other Culex sp. but in lower numbers. Since only young instars could be obtained and this species has a long life span a more intense investigation should be carried out to evaluate their full potential as biological control agents. The adults of certain species have also been shown to predate on adult mosquitoes (Gordon 1922). Thus the combined effort of the utilization of adults and nymphs may well reduce the incidence of this vector. Johnson et.al. (1975) reports of a characteristic behaviour known as "wasteful killing" whereby upon satiation encountered prey are killed but not eaten. This he observed in

his experiment with Daphnia sp. in this studies all the prey seen were eventually eaten. This would be a useful concept in reducing Ae. aegypti as numbers killed are of more value than the quantity of food devoured in assessing the effects of predation.

Lounibos (1979) and Trpis (1973) observed seasonality exhibited by both the predators and the prey. In Kenya, Lounibos (1979) observed that the dry season reduces populations and this increases the time lag between peaks in predators and prey abundance after the onset of the rains as the prey emerges almost immediately. A similar pattern is seen in these parts from the study of breeding in tree-holes (see chapter 4 part 1), where Ae. aegypti were most abundant in May-July there were few predators around till their peak abundance in August when numbers of the prey have already dwindled to the drier conditions. Tox. brevivalpis however avoids extinction as the fourth instars can undergo 6 months of starvation and survive in damp mud (Muspratt 1951).

In the absence of any alternative prey Odonata nymphs eat more Ae. aegypti followed by Tox. brevivalpis and then Culex tigripes.

Ae. aegypti avoids significant predation as it normally breeds where Tox. brevipalpis does not i.e peridomestic containers whilst the predators have feral habitats. Lutzia and Odonata naiads still feed upon them in the domestic containers.

The incidence of predators breeding in the domestic pots was however of little significance in the villages surveyed. Of the 26 visits made to each village, at Amasaman predators were reported on 18 occasions and these comprised of Coleopters and Hemipterans and Odonata species (see Chapter 4 part 2) At Danfa mainly Odonata naiads were observed (16<sup>times</sup>) and occasionally Hemipterans times and on each sampling occasion not more than between 10-15 pots had predators in them. The total number of predators in each pot was few. Service (1970) reports the efficient predation of mosquito larvae by tadpoles (Rana sp.). It was difficult to get any tadpoles to feed in this survey. He concludes that it is difficult to assess the importance of predators as there are so many possible alternative prey for example chironomid larvae which also existed in large numbers in the peridomestic pots of both villages.

In further biological control programmes all three predators can be used effectively but more care has to be taken in planning times of release. The available habitats of the prey should be considered first before a specific predator is released.

### 3.9 STUDIES ON THE LIFE BUDGET OF AEADES AEGYPTI IN TREE-HOLES AT LEGON

#### 3.9.1 Introduction

It is valuable in evaluating control programmes to have quantitative information on the population dynamics of the pest. Measurements of actual numbers of individuals in a generation passing through each stage of development is thus a prior requirement for ecological research. Ecological life tables can then be described as a summary of the vital statistics of a population by a record of sequential measurements of individuals revealing population change of the organism throughout its life span in a most natural environment. They could also provide an indication of the way in which the environment can be modified to reduce the size of the population under study. Service (1976) points out that this technique of constructing life tables for mosquitoes is obviously new because until recently there were no such data

whilst there were some for many agricultural animals.

Southwood (1972) carried out an investigation into the life budget of Ae. aegypti in Thailand. He obtained data from sampling the major breeding containers and found that the greatest mortality during the cooler months occurred in the fourth instar and during the hot months it was during the first instar that larvae mortality was greatest.

Other life tables studies carried out on mosquitoes include studies on Anopheles gambiae complex (Service 1971, 1973) in Kenya. It was observed that mortalities were highest in the fourth instars. Lakhani and Service (1974) studied Aedes cantans which has a very long life cycle and they found out that mortality is most intense in the younger stages and the individuals which survive to a more advanced stage have a relatively high expectation of survival.

In all these observations data were obtained from continuous and intense studies on a single habitat and not by sampling different populations in a number of similar habitat. On the Legon campus since feral populations seemed to be the most abundant and their habitats were mainly tree-holes, it was decided to carry out investigations into populations breeding in trees of a particular species

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(Peltophorus pterocarpum) over a period of time to find out how effective tree-holes were as habitats and their contribution to adult population in an environment.

Critics may, however, point out that a tree-hole is a small habitat and is therefore liable to rapid desiccation. This is true but the investigation was carried out during a rainy season period (March-May) and the tree-holes were situated such that the drying effect of the wind was minimal. Therefore with the addition of a little amount of water occasionally, larval populations could be maintained for a long time. To estimate relative instar mortalities it is necessary to design experiments in the laboratory to assess the contribution made by each instar stage to overall mortality (K). This finding will indicate which stage contributes most to a reduction in Ae. aegypti populations at certain densities. This knowledge can then be related to field observations.

### 3.10 MATERIALS AND METHODS

#### 3.10.1 Key mortality factors

An investigation to analyse which of the various mortality factors  $k_1 - k_4$  was density dependant was conducted.

A series of experiments was carried out in the laboratory by maintaining different larval densities and recording all the vital information about their lives. The beakers (150ml) were seeded with either eggs or first instars. The numbers and size of head capsules and the mortalities were recorded daily. The densities maintained were 10, 39, 50, 100, 150, and 270. There were three replicates for each density.

#### 3.10.2. Effects of Food on Life Budgets

It is known that the amount of food may affect populations of Ae. aegypti. To this effect three generations were experimented with in the laboratory by varying the amount of food given to each of them. Generation 1 was given just enough food but the water was changed once in three days so these larvae were the least disturbed. Generation 2 was given more than enough food and the water was changed every other day. Generation 3 was treated similarly but there was just adequate food. Life tables were calculated from the values obtained.

#### 3.10.3 Obtaining data from tree-holes

To obtain data for life tables one of the experimental trees was sampled regularly to determine numbers entering

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successive instars. This experimental tree was tall, had a dense canopy and a water storing capacity of  $2\frac{1}{2}$  litres. Since the hole was deep the water was stored for long periods. For a time specific life table, sampling was carried out at two day intervals and the number of larvae in each stage was recorded. To do this the water in the hole was stirred vigorously. One end of a rubber tubing (transparent) was placed in the hole and the other in the mouth. Water was thus siphoned from the tree-hole into a bucket. Some clean water was poured into the hole to rinse it out in case any larvae had been caught in the debris or on the bark. This water was also siphoned out. The sample was then taken to the laboratory and the larvae removed and counted. The sample was returned to the tree-hole after the counting.

To obtain information on the duration of the larval period and the life cycle in tree-holes, the second experimental tree-hole was studied. This tree was also huge and had a water storing capacity of 2 litres. The hole was not too deep but due to the position of the main branches the effect of the wind was minimal. A similar procedure was carried out but in this case the tree-hole

was covered with a gauze cloth to prevent further oviposition or predation. Daily observations were made in this case. The time taken for 50% of the larvae to pass through a stage was recorded as the average developmental time.

Larvae of other species were observed occasionally but they formed a small percentage (2%) and were easily distinguished and avoided when counting. Toxorhynchites brevipalpis was recorded once but since it was a fourth instar it soon pupated without killing too many of the occupants of the hole.

#### 3.10.4 Analysis of sampling data for life tables

In constructing a life budget, it was assumed that the population of Ae. aegypti was stable over the rather short period of the study. Therefore an age distribution was assumed to be equal to the shape of the survivorship curve. To derive these curves it was essential to know the actual instar duration in that particular habitat. On obtaining these values the total number in each instar for all samples was divided by the appropriate instar duration and these values were plotted against age in days of the immature stages. The histograms thus represents stage specific age

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distribution. A curve drawn through the mid points of each histogram represents the mid points in the life of each instar and gives the age specific distribution curve which simulates the time specific adult survivorship curve (Service 1976). From the curve numbers surviving to age  $X$  can be read off and a life budget then constructed based on the percentages of the population entering each stage on each sampling day corrected to 1000. The columns that make up a life budget are:-

- $x$  - age in days
- $n_x$  - no. of larvae surviving to age  $x$
- $l_x$  - no. per 1000 larvae surviving to age  $x$
- $d_x$  - mortality between ages  $x$  and  $x+1$
- $p_x$  - probability that a larva of age  $x$  survive to age  $x+1$
- $q_x$  - probability of a larva of age  $x$  dying before reaching age  $x+1$
- $e_x$  - expectation of the life for individual of age  $x$

Another way to analyse such data is to estimate daily mortality, again assuming that mortality is constant within the instars but not necessarily between them. The numbers entering each instar are obtained from the survivorship curve.

K values are logarithmic measures of the killing power of a mortality factor obtained by subtracting successive values of  $\log lx$  (Varley and Gradwell 1960, 1970). The sums of the k values gives the total mortality ('K') for the generation. For the laboratory density dependant experiments the k values for the different densities were all compared. These tree-hole observations were carried out over a period of 3 months when there were still showers of rain and at a period when predation was known to be low. Sometimes rain/tap water was added to the water in the hole to prevent the tree-hole water from becoming too filthy especially between long periods of rain.

### 3.11 RESULTS

#### 3.11.1 Effects of Food Density on Life Budgets

Key factor analysis to determine the contributions made by the different mortality factors to population changes shows that mortality is due mostly to the effect of factor  $k_4$  which acts between 4th instar and pupa (Table 15a). At low densities  $k_1$ ,  $k_2$  and  $k_3$  fail to contribute significantly to K (total mortality for the generation). At a density of 100,  $k_3$  begins to play a role;  $k_4$  on the other hand is

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Table 15aRecognition of the key mortality factorsNumbers of larvae and pupae of Ae. aegypti that survived at different densities

| Expt. | No. of eggs | L <sub>1</sub> | L <sub>2</sub> | L <sub>3</sub> | L <sub>4</sub> | P     | A   |
|-------|-------------|----------------|----------------|----------------|----------------|-------|-----|
| 1     | 10          | 10             | 10             | 10             | 10             | 10    | 10  |
| 2     | 39          | 39             | 39             | 39             | 32             | 35    | 32  |
| 3     | 50          | 50             | 50             | 50             | 47             | 44    | 42  |
| 4     | 100         | 100            | 100            | 94             | 90             | 85    | 81  |
| 5     | 150         | 150            | 147.2          | 138            | 127            | 122.1 | 108 |
| 6     | 270         | 270            | 268.9          | 257            | 231.1          | 229.  | 210 |

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Table 15b

Assessing the individual mortality factors  $k_{1-4}$ , and thus determining 'K' for different densities of Ae aegypti larvae.

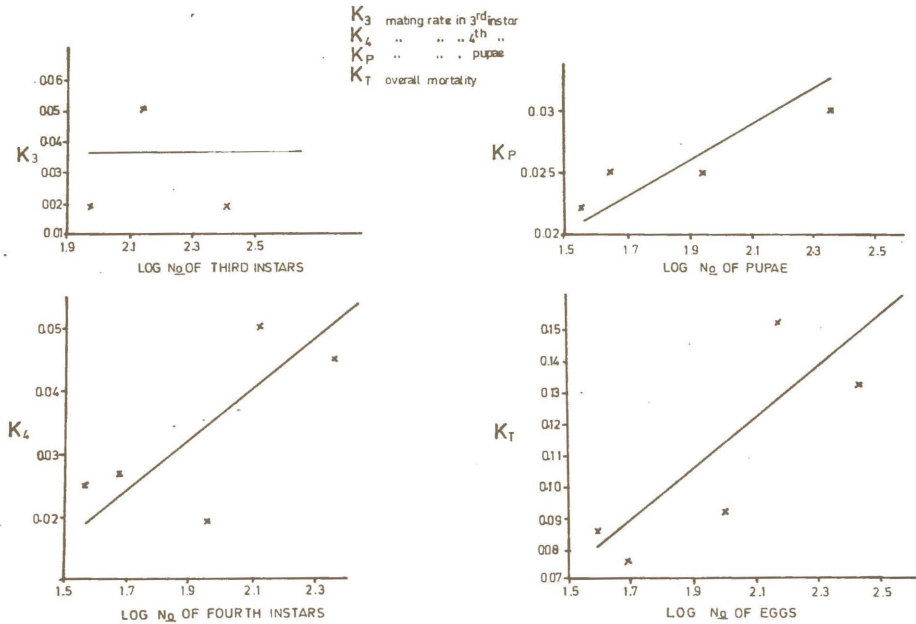
| Expt | Stage of development<br>( X ) | No. entering stage | lx     | log lx | k     |
|------|-------------------------------|--------------------|--------|--------|-------|
| 2    | Egg                           | 39                 | 1000   | 3      | 0     |
|      | L <sub>1</sub>                | 39                 | 1000   | 3      | 0     |
|      | L <sub>2</sub>                | 39                 | 1000   | 3      | 0     |
|      | L <sub>3</sub>                | 39                 | 1000   | 3      | 0     |
|      | L <sub>4</sub>                | 37                 | 948.70 | 2.975  | 0.025 |
|      | P                             | 35                 | 897.43 | 2.953  | 0.022 |
|      | A                             | 32                 | 820.51 | 2.914  | 0.039 |
|      |                               |                    |        | K =    | 0.086 |
| 3    | Eggs                          | 50                 | 1000   | 3      | 0     |
|      | L <sub>1</sub>                | 50                 | 1000   | 3      | 0     |
|      | L <sub>2</sub>                | 50                 | 1000   | 3      | 0     |
|      | L <sub>3</sub>                | 50                 | 1000   | 3      | 0     |
|      | L <sub>4</sub>                | 47                 | 940    | 2.973  | 0.027 |
|      | P                             | 44                 | 888    | 2.948  | 0.025 |
|      | A                             | 42                 | 840    | 2.924  | 0.024 |
|      |                               |                    |        | K =    | 0.076 |

Table 15b Cont.'d

| Expt. | Stage of development ( x ) | No. entering stage nx | lx     | log lx | k     |
|-------|----------------------------|-----------------------|--------|--------|-------|
| 4     | Egg                        | 100                   | 1000   | 3      | 0     |
|       | L <sub>1</sub>             | 100                   | 1000   | 3      | 0     |
|       | L <sub>2</sub>             | 100                   | 1000   | 3      | 0     |
|       | L <sub>3</sub>             | 94                    | 940    | 2.973= | 0.027 |
|       | L <sub>4</sub>             | 90                    | 900    | 2.954  | 0.019 |
|       | P                          | 85                    | 850    | 2.929  | 0.025 |
|       | A                          | 81                    | 810    | 2.908  | 0.021 |
|       |                            |                       |        |        |       |
| 5     | Egg                        | 150                   | 1000   | 3      | 0     |
|       | L <sub>1</sub>             | 150                   | 1000   | 3      | 0     |
|       | L <sub>2</sub>             | 147                   | 980    | 2.991  | 0.009 |
|       | L <sub>3</sub>             | 138                   | 920    | 2.963  | 0.053 |
|       | L <sub>4</sub>             | 127.10                | 818    | 2.912  | 0.051 |
|       | P                          | 122.2                 | 814    | 2.910  | 0.002 |
|       | A                          | 108                   | 720    | 2.873  | 0.037 |
|       |                            |                       |        |        |       |
| 6     | Egg                        | 270                   | 1000   | 3      | 0     |
|       | L <sub>1</sub>             | 270                   | 1000   | 3      | 0     |
|       | L <sub>2</sub>             | 268.9                 | 995.18 | 2.997  | 0.003 |
|       | L <sub>3</sub>             | 257                   | 951.80 | 2.978  | 0.019 |
|       | L <sub>4</sub>             | 231.35                | 856.66 | 2.932  | 0.045 |
|       | P                          | 229                   | 848.00 | 2.928  | 0.030 |
|       | A                          | 210                   | 777.75 | 2.890  | 0.038 |
|       |                            |                       |        |        |       |

FIG 9

GRAPHICAL REPRESENTATION OF THE KEY MORTALITY FACTORS SHOWING THE RELATIONSHIP BETWEEN MORTALITY AND THE POPULATION DENSITY AT THE START OF THE AGE-INTERVAL IN WHICH IT OPERATES



clearly density dependant showing higher mortalities at larger densities.  $K_p$  is slightly density dependant and added up to the other  $k$  values is an important factor. A graphical representation of  $K_T$  (for overall mortality) shows that at high densities the  $k$  values all act to make total mortality density dependant Fig. 9. It should be noted that at high densities,  $k_1$  still fails to contribute to  $K$  and this could probably be due to the fact that this period is too short for any mortality factor to have an effect. Thus adult population is affected more by numbers of fourth instars that mature to the pupal stage than on natality.

Tables 16a-c show the effect of food on survival. Excess food causes a high mortality as seen in generation 2 where  $K = 0.75$  and the highest mortality factor is contributed by  $k_4$ . Generation 3 shows a normal population which had abundant food supply; the larvae were only disturbed occasionally when the water was changed.  $K$  was then 0.411. Generation 1 shows the least disturbed population having just adequate food. The lowest  $K$  value was recorded here, 0.11. The data are exhibited graphically in Fig. 10 showing the different survivorship curve. These laboratory observations do not necessarily imply the state of affairs that exist in real life as seen in the next section.

Table 16a

Life table of Ae. aegypti : - Generation 1

| x              | nx | lx     | dx     | px    | qx     | ex     | log lx | k    |
|----------------|----|--------|--------|-------|--------|--------|--------|------|
| Eggs           | 90 | 1000   | 33.43  | 0.966 | 0.033  | 5.891  | 3      | 0.0  |
| L <sub>1</sub> | 87 | 966.57 | 22.22  | 0.977 | 0.0229 | 5.490  | 2.698  | 0.01 |
| L <sub>2</sub> | 85 | 944.35 | 0.0    | 1.000 | 0.000  | 5.028  | 2.970  | 0.00 |
| L <sub>3</sub> | 85 | 944.35 | 111.11 | 0.882 | 0.1176 | 4.072  | 2.950  | 0.05 |
| L <sub>4</sub> | 75 | 833.25 | 22.22  | 0.973 | 0.0266 | 3.268  | 2.923  | 0.02 |
| Pupa           | 73 | 811.03 | 22.22  | 0.973 | 0.0266 | 1.493  | 2.904  | 0.01 |
| Adults         | 71 | 788.81 |        |       |        | 0.5000 | 2.893  |      |

K = 0.1

- x - duration
- nx - no. larvae surviving to age x
- lx - no. per 1000 larvae surviving to age x
- dx - mortality between ages x and x+1
- px - probability that a larvae of age x survives to age x+1
- qx - probability of a larvae of age x dying before reaching age x+1
- ex - expectation of the life for individuals of age x.

Table 16b

Life table of Ae. aegypti : - Generation 2

| x              | nx | lx     | dx     | px    | qx     | ex    | log lx | k    |
|----------------|----|--------|--------|-------|--------|-------|--------|------|
| Eggs           | 85 | 1000   | 176.80 | 0.823 | 0.1768 | 3.760 | 3      | 0.09 |
| L <sub>1</sub> | 77 | 823.2  | 105.84 | 0.871 | 0.1285 | 3.267 | 2.915  | 0.06 |
| L <sub>2</sub> | 61 | 717.36 | 105.84 | 0.852 | 0.1475 | 2.690 | 2.850  | 0.09 |
| L <sub>3</sub> | 52 | 611.52 | 235.20 | 0.615 | 0.3846 | 2.190 | 2.781  | 0.21 |
| L <sub>4</sub> | 32 | 376.32 | 164.64 | 0.562 | 0.4375 | 2.000 | 2.572  | 0.25 |
| Pupa           | 18 | 211.68 | 23.52  | 0.889 | 0.1111 | 1.470 | 2.321  | 0.05 |
| Adults         | 16 | 188.16 |        |       |        | 0.500 | 2.273  |      |

K = 0.75

- x - duration
- nx - no. larvae surviving to age x
- lx - no. per 1000 larvae surviving to age x
- dx - mortality between ages x and x+1
- px - probability that a larvae of age x survives to age x+1
- qx - probability of a larvae of age x dying before reaching age x+1
- ex - expectation of the life for individuals of age x.

Table 16c

Life table of *Ae. aegypti* : - Generation 3

| x              | nx | lx     | dx     | px     | qx    | ex    | log Lx | k     |
|----------------|----|--------|--------|--------|-------|-------|--------|-------|
| Eggs           | 85 | 1000   | 94.48  | 00.905 | 0.095 | 4.512 | 3      | 0.044 |
| L <sub>1</sub> | 77 | 905.52 | 117.32 | 0.870  | 0.130 | 3.951 | 2,956  | 0.060 |
| L <sub>2</sub> | 67 | 788.20 | 94.09  | 0.880  | 0.120 | 3.372 | 2.896  | 0.055 |
| L <sub>3</sub> | 59 | 694.11 | 153.00 | 0.779  | 0.221 | 2.847 | 2.841  | 0.108 |
| L <sub>4</sub> | 46 | 541.11 | 58.81  | 0.891  | 0.109 | 2.167 | 2.733  | 0.050 |
| Pupa           | 41 | 482.30 | 94.10  | 0.804  | 0.196 | 1.446 | 2.683  | 0.094 |
| Adults         | 33 | 388.21 |        |        |       | 0.500 | 2.589  |       |

K = 0.411

x - duration

nx - no. larvae surviving to age x

lx - no. per 1000 larvae surviving to age x

dx - mortality between ages x and x+1

px - probability that a larvae of age x survives to age x+1

qx - probability of a larvae of age x dying before reaching age x+1

ex - expectation of the life for individuals of age x.

3.11.2 Tree-hole observations3.11.2.1 Variability in longevity of *Ae. aegypti* in different habitats

Developmental variables as obtained from observations on *Ae. aegypti* life cycle in the tree-holes and in the laboratory are exhibited in Table 17a. Eggs used for this observation had previously been kept at an 80% relative humidity at room temperature 27°C. It appears that the third instar larval duration was the longest in the tree-holes probably due to the very high densities of larvae competing for a limited amount of food. These observations are compared to similar ones carried out to study the instar durations under laboratory conditions where there was adequate food space and temperature. It therefore acted as a sort of control experiment. In these observations the fourth instars exhibited the longest duration in the laboratory experiments. The pupal durations are however comparable.

Table 17a  
Larval durations in various habitats

| Habitat    | Developmental time, days |     |     |     |     |      | Total |
|------------|--------------------------|-----|-----|-----|-----|------|-------|
|            | eggs                     | 1st | 2nd | 3rd | 4th | pupa |       |
| Tree-holes | 0.33                     | 1.1 | 2.4 | 4.1 | 3.6 | 2.0  | 13.53 |
| laboratory | 0.41                     | 0.5 | 1.2 | 2.5 | 3.1 | 2.1  | 9.72  |

FIG.10 THE EFFECT OF DIFFERENT AMOUNTS OF FOOD ON SURVIVAL  
OF THREE GENERATIONS OF AEADES AEGYPTI.

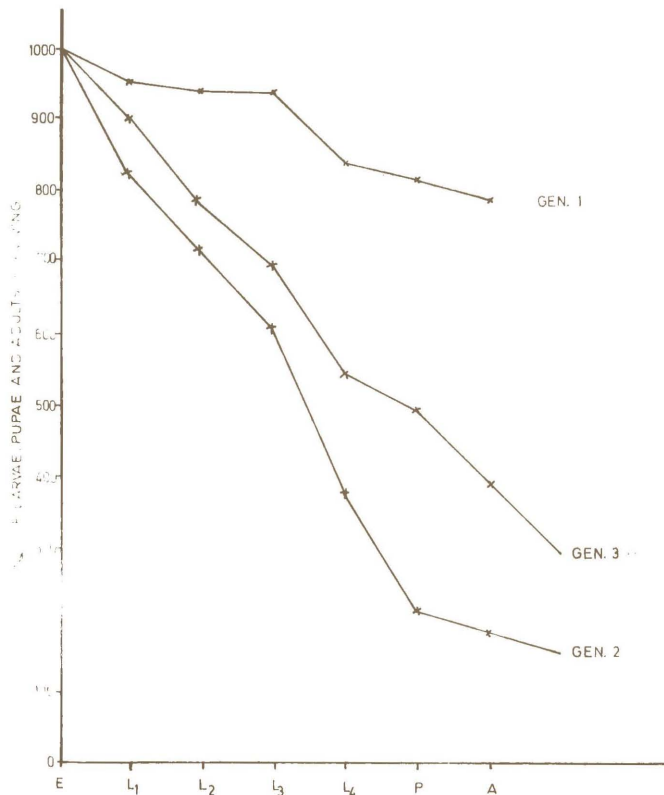


Table 18

Numbers of larvae and pupae of Ae. aegypti obtained from successive samples from a tree-hole. (Mar. - May)

| Date   | Sample | No. of larvae and pupae |      |      |      |       | Remarks   |
|--------|--------|-------------------------|------|------|------|-------|---|
|        |        | 1st                     | 2nd  | 3rd  | 4th  | pupae |   |
| 2:3:82 | 1      | 174                     | 16   | 4    | 10   | 32    | Rained previous night                                       |
|        | 2      | 12                      | 150  | 20   | 3    | 8     | 1 <u>Tox. brevivalpis</u><br>(2nd) removed                  |
|        | 3      | 8                       | 111  | 87   | 10   | 0     |   |
|        | 4      | 204                     | 91   | 137  | 50   | 3     | Few <u>Ae. luteocephalus</u><br>seen (20). Rained<br>again. |
|        | 5      | 60                      | 151  | 143  | 75   | 9     |   |
|        | 6      | 22                      | 87   | 83   | 150  | 16    | Tap water was added   |
|        | 7      | 12                      | 49   | 61   | 91   | 82    |   |
|        | 8      | 10                      | 24   | 16   | 78   | 45    |   |
|        | 9      | 4                       | 16   | 14   | 30   | 25    |   |
|        | 10     | 162                     | 175  | 21   | 25   | 3     | Rained night before.<br>A few <u>C. decens</u> seen         |
|        | 11     | 132                     | 240  | 306  | 25   | 11    | Rained at dawn  |
|        | 12     | 25                      | 57   | 376  | 90   | 10    |   |
|        | 13     | 7                       | 55   | 326  | 111  | 8     |   |
|        | 14     | 20                      | 217  | 156  | 88   | 3     |   |
|        | 15     | 116                     | 265  | 186  | 60   | 11    | Rained previous night                                       |
|        | 16     | 60                      | 92   | 143  | 95   | 37    |   |
|        | 17     | 20                      | 72   | 186  | 87   | 23    |   |
|        | 18     | 16                      | 45   | 160  | 70   | 12    | Water added to the<br>hole                                  |
|        | 19     | 4                       | 20   | 1166 | 93   | 15    |   |
| 1:5:82 | 20     | 2                       | 10   | 90   | 78   | 16    |   |
|        | Total  | 1070                    | 1943 | 2630 | 1319 | 369   |   |

Table 19

Life table of Aedes aegypti breeding in a tree-hole

|    | nx   | lx   | dx | px     | qx    | ex    |
|----|------|------|----|--------|-------|-------|
|    | 1025 | 1000 | 98 | 0.9021 | 0.098 | 7.372 |
|    | 923  | 902  | 92 | 0.8972 | 0.103 | 7.164 |
|    | 830  | 810  | 74 | 0.9091 | 0.091 | 6.826 |
|    | 755  | 736  | 48 | 0.9340 | 0.067 | 6.325 |
| 4  | 705  | 688  | 44 | 0.936  | 0.064 | 5.693 |
| 5  | 660  | 644  | 50 | 0.908  | 0.092 | 5.087 |
| 6  | 598  | 585  | 70 | 0.883  | 0.117 | 4.558 |
| 7  | 530  | 517  | 78 | 0.849  | 0.151 | 4.101 |
| 8  | 450  | 439  | 63 | 0.856  | 0.144 | 3.638 |
| 9  | 385  | 376  | 59 | 0.843  | 0.157 | 3.102 |
| 10 | 325  | 317  | 78 | 0.753  | 0.247 | 2.620 |
| 11 | 245  | 239  | 54 | 0.774  | 0.226 | 2.125 |
| 12 | 190  | 185  | 39 | 0.789  | 0.211 | 1.441 |
| 13 | 150  | 146  |    |        |       | 0.500 |

FIG. 11 AGE DISTRIBUTION AND SURVIVALSHIP CURVE FOR THE IMMATURE STAGES OF Aedes Aegypti

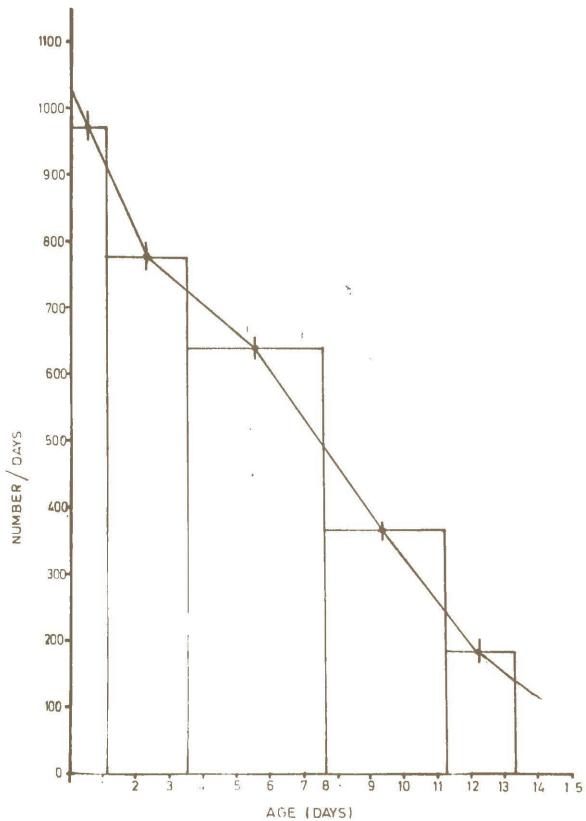


Table 20  
Instar mortalities of Aedes aegypti in tree-hole

| Instar | Age in days at beginning of instar ( $t_i - 1$ ) | No. entering instar ( $St_i - 1$ ) | Death in instar ( $D_i$ ) | Relative proportion dying in instar ( $\frac{D_i}{(St_i - 1)}$ ) | Proportion dying daily in instar $1 - \frac{(St_i)^k}{(St_i - 1)}$ | K        |
|--------|--|------------------------------------|---------------------------|--|--|----------|
| 1      | 0.0  | 1025                               | 115                       | 0.1121   | 0.1120   | 0.052    |
| 2      | 1.1  | 910                                | 185                       | 0.2000   | 0.0887   | 0.097    |
| 3      | 3.5  | 728                                | 230                       | 0.3159   | 0.0882   | 0.165    |
| 4      | 7.8  | 498                                | 248                       | 0.4979   | 0.1938   | 0.299    |
| P      | 11.2   | 250                                | 105                       | 0.4200   | 0.239  | 0.237    |
| A      | 13.2   | 145                                |                           |  |  | K=0.85   |
|        |  |                                    |                           |  |  | K = 0.85 |

3.11.2.2 Life tables of Aedes aegypti population  
in the tree-holes

Numbers of larvae and pupae caught on successive sampling days in the tree-holes are recorded in Table 17. The average number of larvae and pupae that can inhabit this hole (capacity 2½ litres) was 365.85 (range 89-714). Mortality was highest at the very high densities which usually occurred after rain storms. The life table (Table 18) shows a high survival expectation in the earlier instars than in the older ones and this point is further proved by the K value. (Table 19) where  $k_4$  was the highest mortality contributing factor to K.

The graphical representation of the budget is exhibited in the survivorship curve (Fig. 11). The curve shows a gradual decline in the early instars when compared to the rapid curve in the later instars which suggests higher mortalities in the 3rd and 4th and pupal stages.

3.12 DISCUSSION

Life tables usually describe in terms of population density the numbers of individuals of a generation passing through each stage and the contribution of these individuals to the next generations. They can be used to predict

forecasting of climatically induced out-breaks of the pest and in making prognoses of the effect of changes in cultural or control practices.

Life tables studied over a period of time give details of the effects of environmental conditions on population densities in their habitats at a particular time or season which are essential in planning control programmes. Such studies as pointed out by a group of W.H.O. scientists on mosquito ecology (1967) makes it possible to recognise environmental factors that will be important in population fluctuation and the relationship of mortality and dispersal at each stage of the life cycle. The term key factor (Morris 1959) helps one detect whether mortality is delayed or inversely density dependant and which factors contribute to overall mortality.

From the results of the study of Ae. aegypti in the hole we can conclude that adult populations emerging from tree-holes are mainly determined by the survival of the fourth instars to mature into pupae rather than the numbers of eggs laid as the most significant mortality occurs at  $k_4$ . The survivorship curves obtained are more like a compromise between Slobodkins's (1961) Type II and I which are diagonal,

representing constant mortality and negatively skewed which suggests mortality at the latter stages.

Life cycle duration, it would appear, differs greatly upon several factors, for example the inhibiting effect of high densities and the amount of food available. Table 17b summarises results obtained by Southwood (1972) and Christophers (1960), in earlier experiments which are entirely different from results obtained in this present study.

Table 17b Larval durations obtained by previous authors

| Author/<br>Habitat         | Developmental time, days |           |      |      |       | Total |
|----------------------------|--------------------------|-----------|------|------|-------|-------|
|                            | eggs                     | 1st & 2nd | 3rd  | 4th  | pupae |       |
| Southwood<br>(1972)        |                          |           |      |      |       |       |
| a) ant traps               | 2.59                     | 4.57      | 4.16 | 6.84 | 1.95  | 20.40 |
| b) flower<br>pots          | 2.88                     | 3.98      | 3.22 | 5.44 | 1.28  | 16.95 |
| Christophers<br>(1960)     |                          |           |      |      |       |       |
| Laboratory<br>observations | 2.10                     | 2.90      | 0.84 | 1.00 | 2.00  | 9.14  |

Tree-holes have abundant organic matter compared to the habitats described by Southwood (1972) and Christophers (1960) and will definitely alter pre-imaginal populations in a different way. The only comparable stage is the pupal stage and it appears that adult emergence is little affected by environmental changes, except temperature.

Observations on laboratory results indicate that the early instars show an extreme tolerance for high density and this could be attributed to their short developmental time and size. They need minute quantities of food and invariably large percentages of them pass on to the next stage. It would appear that  $k_3$  plays an important role in these laboratory observations at the densities at which it operates. These small laboratory systems actually represent extreme cases which may be rare or perhaps never realized in the open but they give an indication as to the effects of high densities and which of the key factors contributes the most. They also emphasize that life budgets are easily affected by prevailing environmental conditions.

In tree-holes several factors are bound to affect life budget values and these will include predation, desiccation (amount of rainfall), the lethal contribution of

of pollution in the water (toxicity) and over population. This pollution is brought about by organic substances from the tree or chemical substances produced by high concentration of larvae which is lethal to the younger instars and acts to a large extent as a method of self regulation.

Service (1974) points out that many types of predators can exist in small habitats and most are able to endure severe environmental conditions. In this study Tox. brevipalpis was found only once probably because the months chosen for this study are the low breeding seasons of the predator. An earlier study was attempted just at the latter stages of the rains in June - August 1981 but heavy mortality due to predation made it almost impossible to obtain any conclusive data. The data<sup>is</sup> however available in appendix 4. Although Service (1970) could not prove the effectiveness of ants as predators it is suggested that another look should be taken at Oecophylla longinoda concerning its role in scavenging stranded larvae, and eating eggs, because they appear to be constantly around many tree-holes and when the water is removed for inspection they march into the hole and scavenge around. Thus any larvae left on the bark may easily be devoured.

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Desiccation is another extremely important factor as this observation could only be carried out in the rainy season. In the dry season a tree-hole's contribution to adult population would be negligible. After some time water in the hole starts to go turbid due to the accumulation of organic material. However after the next rains the concentration is very much diluted and larval populations are able to survive again. Toxic substances could also contribute to mortalities of the latter instars.

Over population seems to be the major factor in determining life cycle durations in this tree-hole study. It would appear that large numbers of eggs are laid at the water level on the tree bark due to availability of suitable conditions i.e. a wet, rough and dark surface. So whenever the hole is filled above that level most of the eggs hatch as they have been already conditioned and are now being exposed to water containing humus, and some agitation. Thus 714 larvae in 2½ litres of water (see Table 11, sample 11) are clearly too many and subsequently mass mortalities follow.

Since instars 1 and 2 have so short a duration and the larvae are small, most reach the third instar and stay in that stage for a long time before maturing, and as their

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numbers and individual requirements are large, competition sets in. Individuals that mature to instar 4 often die due to all the possible mortality factors especially overcrowding and toxic effects. This stage appears likely to be the density dependant one on which population regulation of adult numbers depends. It was very common to observe dead 4th instars in the hole. Probably more third instars failed to develop into 4th instars than  $k_3$  actually accounts for due to the extended duration.

The presence of predators would reduce over-crowding and probably shorten the life cycle of survivors. It is hoped that the presence of the gauze cloth and the frequency of sampling did not have any effect on the maturation process of the larvae.

Of the initial numbers of 1st instars only 34.48 per cent mature into pupae and as such about only 30 per cent adults may emerge. Therefore the contribution of this tree-hole to adult population is not too great and these percentage will however differ from season to season when factors like predation and overcrowding due to other mosquito species being present in large numbers, become more important factors than overcrowding within one species

and toxic effects that seem to be the main regulatory factors in this season.

The reality of a density dependant regulatory mechanism is evident in instar 4 at high densities for both experiments in the laboratory and in the field. This is similar to Service's (1972) study on Anopheles gambiae. Southwood's (1972) observation again proves that key mortality factors are greatly dependant on environmental conditions and in defining mortality factors for any organism the ecology of the environment should be carefully analysed and described as contributing to the data obtained.

CHAPTER FOUR

SEASONAL VARIATIONS OF AEADES AEGYPTI  
AND OTHER AEADES SPECIES

PART I

4.0 Observation on Aedes Aegypti and other Mosquitoes  
Breeding in Tree-Holes

4.1 Introduction

Tree-holes are probably the most widespread of container habitat as many species of several genera of mosquitoes breed in them; and as such, eggs, larvae and adults have been collected from them (Dunn, 1926, 1927a, b; Christophers 1960; Service, 1965, 1976; Tripis 1972a;). Species that breed in tree-holes are those that prefer clean rain water for oviposition and for larval development and there is a high frequency of the presence of the same species occurring both in receptacles and other temporary water storage containers in urbanized areas in tree-holes.

Soper (1967) stated that Ae. aegypti was originally a tree-hole breeder and is now adapted to human habitations. That mosquitoes breed in tree-holes has long been recognised and there are reports of eradication programmes which include the blocking of tree-holes with cement. This study was

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undertaken to obtain additional information on the breeding habits of Ae. aegypti and to find out which other species coexist with Ae. aegypti in these tree-holes and their prevalence in this area. It is <sup>of</sup> significant interest to find out the role that tree species plays in the selection of its Culicine inhabitants although Taylor (1934) reported no evidence of tree species preference for oviposition. Since a considerable amount of rainfall is required to fill most tree-holes this study was carried out in the main rainy season lasting from May - July, with continued observations in the dry months of August - September, on the dried debris collected in the holes and a few observations in October-November during which there were few showers. There were many tree-holes on the University campus most of the ornamental trees were Delonix regia which has many natural cavities. Tree-holes are formed in several ways. Kitching (1971a) defines a tree-hole as any cavity or depression existing in or on a tree. (See Plate 6). Two main types exist. Pans are those that maintain an unbroken bark lining throughout their existence and rot holes that lack this lining and the hole penetrates to the sap wood. Rot holes normally need an external agent of a

4.2 MATERIALS AND METHODS

4.2.1 Description of Experimental Sites

4.2.1.1 Tree-holes

For this study six well developed trees were selected at random on the University campus. The topography can be described as being generally low with a few low hills, and since the vegetation is well cared for the general area has plenty of grass lawns and many different types of trees and shrubs.

Tree-hole 1. Peltophorum pterocarpum (Fam. Caesalpiniaceae) was found near the Zoology Department and the hole was about 20 cm deep. Its widest portion was about 25 cm long. The hole contained approximately 1,500cc of water. The hole is situated at a height of about  $1\frac{1}{2}$ m and it retained water for a long time due to a dense canopy. This factor was enhanced by the tree's two main branches which protected the hole from the wind and the sun. The hole was normally filled with lots of humus.

Tree-hole 2. Cassia nodosa (Fam. Caesalpiniaceae); near the Zoology Department. Two holes are recorded here,  $\frac{3}{4}$ m and  $1\frac{1}{2}$ m off the ground respectively. The first hole was

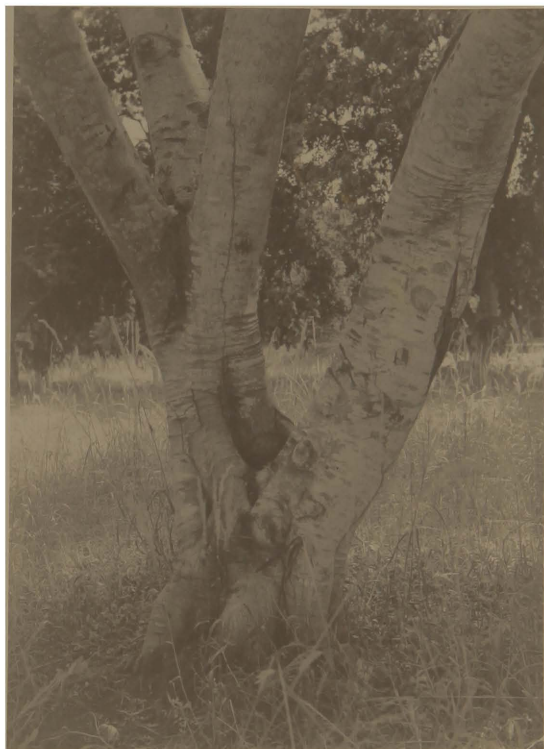


Plate 6: Cassia nodosa (T.H.2) showing the 2 tree holes at different heights

result of damage by man/animal or physical agencies to start them off.

As such the capacity of a tree-hole varies greatly and Dunn (1927) in his observations recorded a range of water holding capacity from 20cc to 90 litres. The amount of water found at any time depends on the amount of rainfall, the density of the canopy, the formation and location of the hole on the tree.

Artificial tree holes have been fabricated to facilitate the study on the fauna. Dunn (1927b) used bamboo cups and tins, Service (1965) used gourds to enable studies during the dry seasons.

In this research empty canned beer tins were used and placed in trees that did not have holes but had been reported as having them elsewhere (Dalziel, 1920). This would increase the number of tree species worked with and the effect of height could also be studied.

much bigger than the second one. It was formed out of the two main branches of the tree and could contain 500cc of water. This hole which was filled mainly with sandy soil and very little humus was in the direct path of the wind and as such water was not retained for long periods.

Tree-hole 3. Delonix regia (Fam. Caesalpiniaceae) a young tree on an open lawn with a small hole about two metres off the ground which could contain approximately 350cc of water. There was very little debris or sand in it and water was not retained for long periods at all as the wind had a drying effect and the canopy was very thin. Thus whenever larvae were caught the water was always relatively clean.

Tree-hole 4. Delonix regia (Fam. Caesalpiniaceae). Near Balme Library. The hole here was small but very deeply set; as such the water was always filthy and full of other aquatic organisms and always had a pungent smell. The whole area was damp as larger trees provided shade.

Tree-hole 5. Peltoporum pterocarpum (Fam. Caesalpiniaceae) also very near Balme Library. The hole was rather large and resembled a basin with a wide rim. The hole could contain 1,500cc of water. It was filled with plenty of broken twigs, flowers, faecal matter and cuticle of insects

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that probably inhabited the tree-hole when it was dry. The water was not retained for too long because although there was a dense canopy the wind played a major role and it dried up very fast. The water was relatively clean, but when it stayed for a long time it turned a very red colour and had a strong odour.

Tree-hole 6. Delonix regia (Fam. Caesalpiniaceae) a large shady tree with a large and deep hole which could contain 2,000cc of water. Due to the stout trunk and the dense canopy, water was retained for long periods. It was also filled with a lot of humus so the water got dirty very quickly.

No matter the number of holes on a tree, the tree was always considered as a unit.

#### 4.2.1.2 Ovitraps

It was noticed that only two species of the trees on campus had adequately sized holes in them although many different species of trees have been recorded as having holes (Dunn, 1927; Service, 1965) in other parts of West Africa. To increase tree species variety it was decided to place tin cans half filled with water and other debris e.g. dried leaves, on branches of other species of

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trees to find out the effect of height of the 'hole' and numbers of mosquitoes species that visited it (see Plate 7). The trees chosen were;-

O.T.1. Samanea saman (Fam. Mimosaceae). Tin can placed at a height of 2½m in a forming rot hole.

O.T.2. Delonix regia (Fam. Caesalpiniaceae). There were as many as 10 little holes in this tree but most were too small to retain water for long periods. So a tin can was placed in one of the little holes. Height 1m.

O.T.3. Mangifera indica (Fam. Anacardiaceae). Tin can was placed at a height of 1m off the ground.

O.T.4. Azadiracta indica (Fam. Meliaceae). Tin can was placed between the two main branches of the tree at a height of about 1½m.

O.T.5. Citrus sp. (Fam. Rutaceae) Tin can placed in one of the upper branches at a height of 1½m.

O.T.6. Elaeis guineensis (Fam. Palmae) Tin can was placed in one of the lower branches at a height of ¾m.

O.T.7. Ficus platyphylla (Fam. Moraceae) Tin can was not even placed on the tree as the tree had most of its branches 10m off the ground and was as such placed at the bottom of the tree in between two buttress roots.



Plate 7: Beer can filled with water and debris acting as an Ovitrap for mosquitoes placed on the branches of a Citrus tree, O.T.5.

O.T.8. Musa sp (Fam. Musaceae). The tin can was placed on one of its branches about 2m from the ground.

O.T.9. This tin was just placed within a clump of grass.

#### 4.2.2 Methods for Data Collection

##### 4.2.2.1. Monthly occurrences of different species

In an attempt to obtain information of the different species that bred in the tree-holes in this area, the tree-holes were sampled two days after a rain storm and thereafter at intervals of 3-4 days so long as there was water in them. Depending on the size and shape of the hole either a soup laddle or a 50ml beaker was used to sample. Three dips were made for each sample taking care that the larvae were not unduly disturbed to make them stay at the bottom. Any excess water was poured back into the hole and the larvae (preferably 4th instars and pupae) were put into well labelled bottles. The samples were then taken to the laboratory and counted; they were then put into larger bottles. More water and food were added and they were reared to the adult stage. The different species were noted and their numbers recorded.

#### 4.2.2.2. Ovitraps

These were sampled weekly removing the pupae and fourth instars only. Similarly the larvae/pupae were put into well labelled glass containers and brought to the laboratory where they were reared into adults and identified. The tins were filled with water whenever the level went low to be able to obtain continuous breeding in them. Two clay pots were also placed in the garden near the laboratories to investigate the different species present there too.

#### 4.2.2.3. Dried Debris

Since it is known that Aedes sp. survives the drought period in the egg stage it is expected that even after the rains are over there should be some eggs in the holes.

The hatching of mosquito larvae from material collected in tree-holes has been reported in Nigeria by Dunn (1926), Taylor (1934), Service (1965) and Lambrecht and Peterson (1976). Therefore when the holes were dry the debris including bits of bark were scrapped off and put into polythene bags and labelled. These samples were brought to the laboratory and flooded with water to which

food (Cerelac) had been added. It is very important that the debris is totally submerged in the water. The total number of larvae was recorded and the larvae were reared to the adult stage.

Identification of species was carried out on larvae and those that had been reared to adult stage using keys by Hopkins (1952) Edward (1941).

#### 4.3 RESULTS

##### 4.3.1 Tree-holes

Collections of larvae in 6 tree-holes were made over a period of 8 months which lasted mainly throughout the rainy season with a few observations in the dry season. Ten different mosquito species were recorded and an analysis of the mosquito species and the proportions (%) in which they occurred in all tree-holes combined is listed in Table 21.

Aedes aegypti was recorded in all the tree-holes and had the highest frequency and density in most cases and in T.H.2 and T.H.5 it formed over 50% of the total number of larvae caught.

Table 22 shows a breakdown of the different species and the tree-holes in which they occurred. Seven of the ten different species were recorded on T.H.1. and the largest number of larvae (1092) were also caught there.

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Table 21

Incidence of The different species of mosquitoes  
breeding in the observed tree-holes.

| Mosquito species  | Percentage % |
|---|--------------|
| <u>Aedes</u> ( <u>Stegomyia</u> ) <u>aegypti</u> ..       | 63.02        |
| " " <u>luteocaphalus</u>                                  | 12.34        |
| " " <u>apicoargenteus</u>                                 | 1.12         |
| " " <u>simpsoni</u> ..                                    | 1.00         |
| " " <u>dendrophilus</u>                                   | 1.08         |
| " ( <u>Aedimorphus</u> ) <u>stokesi</u> ..                | 8.23         |
| <u>Culex</u> ( <u>Culex</u> ) <u>decens</u> ..            | 7.5          |
| <u>Culex</u> ( <u>Neoculex</u> ) <u>horridus</u> ..       | 2.11         |
| <u>Culex</u> ( <u>Culex</u> ) <u>praini</u> ..            | 1.10         |
| <u>Toxorhynchites</u> <u>brevipalpis</u> <u>contradti</u> | 2.5          |

Table 22

Occurrences of different mosquito species collected from different tree-holes in May - December 1981. (percentages in parentheses)

| <u>of</u><br><u>les</u> | <u>Total No.</u><br><u>of Larvae</u><br><u>Collected</u> | <u>Aedes</u><br><u>gypti</u> | <u>Aedes</u><br><u>luteoce-</u><br><u>phalus</u> | <u>Aedes</u><br><u>Stokesi</u> | <u>Aedes</u><br><u>apico-</u><br><u>argenteus</u> | <u>Culex</u><br><u>decens</u> | <u>Culex</u><br><u>horridus</u> | <u>Culex</u><br><u>purina</u> | <u>Tox.</u><br><u>brevipalvis</u><br><u>conradti</u> | <u>A.</u><br><u>simpsoni</u> |
|-------------------------|--|------------------------------|--|--------------------------------|---|-------------------------------|---------------------------------|-------------------------------|--|------------------------------|
| 23                      | 1092   | 575 (53)                     | 194 (18)   | 60 (5)                         | 6 (1)   | 178 (17)                      | -                               | 10 (1)                        | 67 (6)   |                              |
| 17                      | 477  | 217 (45)                     | 143 (30)   | 55 (11)                        | 6 (1)   | 13 (2)                        | -                               | -                             | 5 (1)  | 17 (2)                       |
| 10                      | 765  | 684 (89)                     | 27 (11)  | -                              | -   | -                             | -                               | -                             | -  | -                            |
| 6                       | 38   | 25 (67)                      | 4 (11)   | -                              | -   | 5 (13)                        | -                               | -                             | -  | -                            |
| 12                      | 455  | 195 (48)                     | 32 (8)   | 88 (22)                        | -   | -                             | 58 (15)                         | 23 (6)                        | 1 (1)  | 10 (4)                       |
| 4                       | 231  | 81 (78)                      | 6 (3)  | 28 (12)                        | -   | 6 (3)                         | -                               | -                             | 2 (1)  | -                            |

Table 23

Frequency of occurrences of recorded mosquito species  
from the various tree-holes

| <u>Sample No.</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. apicoargenteus</u> | <u>Culex decens</u> | <u>Culex horridus</u> | <u>Culex purinia</u> | <u>Tox. brevivalpis</u> | <u>Ae. simpsoni</u> | <u>No. of Samples</u> |
|-------------------|--------------------------|--------------------|---------------------------|---------------------|-----------------------|----------------------|-------------------------|---------------------|-----------------------|
| 19                | 15                       | 11                 | 3                         | 8                   | -                     | 3                    | 11                      | 1                   | 23                    |
| 14                | 14                       | 9                  | 1                         | 2                   | -                     | -                    | 1                       | 3                   | 18                    |
| 10                | 4                        | 1                  | -                         | -                   | -                     | -                    | -                       | -                   | 10                    |
| 6                 | 2                        | -                  | -                         | 2                   | -                     | -                    | -                       | -                   | 6                     |
| 10                | 6                        | 8                  | -                         | -                   | 4                     | 4                    | 1                       | 1                   | 10                    |
| 4                 | 2                        | 4                  | -                         | -                   | -                     | 4                    | 2                       | -                   | 4                     |

10 24

A monthly analysis of the different species of mosquitoes in the experimental tree-holes (Figures represent occurrences in each month).

|                           | May | June | July | August | Sept. | Oct.            | Nov. |
|---------------------------|-----|------|------|--------|-------|-----------------|------|
| TH. 1                     |     |      |      |        |       |                 |      |
| <u>Ae. aegypti</u>        | 71  | 56   | 46.5 | 34     | 23    | 32              | 46   |
| <u>Ae. luteocephalus</u>  | 21  | 12   | -    | 18     | 51    | 41              | 8    |
| <u>Ae. stokesi</u>        | -   | 13   | 4    | 3      | 5     | 22              | 17   |
| <u>Ae. apicoargenteus</u> | -   | 1    | -    | 2      | -     | -               | -    |
| <u>C. decens</u>          | 3   | 7    | 44   | -      | -     | -               | -    |
| <u>C. pruinia</u>         | -   | 5    | 1    | 1      | -     | -               | -    |
| <u>T. brevipalpis</u>     | -   | 2    | 1    | 28     | 18    | 4               | 9    |
| TH. 2                     |     |      |      |        |       |                 |      |
| <u>Ae. aegypti</u>        | 65  | 51   | 13   | 41     | 6     | 75 (dry debris) |      |
| <u>Ae. luteocephalus</u>  | 16  | 28   | 44   | 45     | 22    | 10 "            |      |
| <u>Ae. stokesi</u>        | 8   | 10   | 37   | 5      | 46    | 15 "            |      |
| <u>Ae. apicoargenteus</u> | -   | 2    | -    | -      | -     | -               |      |
| <u>C. decens</u>          | 1   | -    | -    | 9      | 11    |                 |      |
| <u>T. brevipalpis</u>     | -1  | 1    | -    | -      | 3     | -               |      |
| <u>Ae. simpsoni</u>       | 6   | 1    | 10   | -      | -     | -               |      |

Table 24 (CONT'D)

|       | May                      | June | July | August | Sept. | Oct. | Nov.                  |
|-------|--------------------------|------|------|--------|-------|------|-----------------------|
| TH. 3 | <u>Ae. aegypti</u>       | -    | 100  | 100    | 84    | 90   | 80                    |
|       | <u>Ae. luteocephalus</u> | -    | -    | -      | 14    | 10   | -                     |
| TH. 4 | <u>Ae. aegypti</u>       | -    | 50   | 85     |       |      |                       |
|       | <u>Ae. luteocephalus</u> | -    | -    | 15     |       |      |                       |
|       | <u>C. decens</u>         | -    | 42   |        |       |      |                       |
| TH. 5 | <u>Ae. aegypti</u>       | -    | 100  | 75     | 58    | 42   | 20<br>(dry<br>debris) |
|       | <u>Ae. luteocephalus</u> | -    | -    | -      | 18    | 22   | 80 "                  |
|       | <u>Ae. stokesi</u>       | -    | -    | 19     | 21    | 24   |                       |
|       | <u>C. horridus</u>       | -    | -    | -      | -     | -    |                       |
|       | <u>T. brevipalpis</u>    | -    | -    | -      | -     | -    | 1                     |
|       | <u>C. pruinia</u>        | -    | -    | 7      | -     | -    | 11                    |
|       | <u>Ae. simpsoni</u>      | -    | -    | -      | -     | -    | 10                    |
|       |                          |      |      | 69     | 90    |      |                       |
|       |                          |      |      | 3      | 10    |      |                       |
|       |                          |      |      | 15     |       |      |                       |
|       |                          |      |      | 3      |       |      |                       |
|       |                          |      |      | 1      |       |      |                       |

The highest number of Toxorhynchites brevipalpis were also recorded in this tree-hole. Aedes aegypti and Ae. luteocephalus formed the largest percentages.

Tree-hole 5 (T.H.5) also had a large number of larvae considering the fewer number of samples taken. Seven different species were recorded Ae. aegypti and Ae. stokesi showing the highest percentages, 48 and 22 respectively.

Not so many different species bred in Tree-hole 2 (T.H.2) and here again Ae. aegypti and Ae. luteocephalus were the most common (43% and 30% respectively) and were recorded together in most samples (Appendix 6).

Tree-holes 3 and 4 (T.H.3 and T.H.4) were not sampled so often as they were small holes and did not retain water for long. In both cases, however, Ae. aegypti was the predominant species forming 89% in T.H.3 and 67% in T.H.4.

Tree-hole 6 was discovered late but samples showed that five different species were recorded; Ae. aegypti having the highest percentage of 78%.

Table 23 shows frequency of occurrences of the different species and in T.H.1 and T.H.2 Ae. aegypti and Ae. luteocephalus occurred very frequently whilst in T.H.5 and T.H.6 Ae. aegypti and Ae. stokesi occurred together very frequently. Toxorhynchites brevipalpis was recorded

most frequently in T.H.1 (11) and in other tree-holes were observed only once or twice.

Culex decens was the most frequently observed Culex species and was recorded in all the tree-holes. Total numbers appear large due to the large numbers of one sample of 128 Culex decens larvae. Toxorhynchites brevipalpis was recorded in 4 out of the 6 tree-holes. Overall, Ae. aegypti occurred most often followed by Ae. luteocephalus and Ae. stokesi whilst Ae. simpsoni and Ae. apicoargenteus occurred often.

Table 24 shows data on the monthly variations of the different species. Although 8 months is too short a time to show any succession in detail, it was noticed that in T.H.1 the highest number of different species occurred in June which is the peak of the rainy season and that Ae. aegypti occurred in all months. The density of this species decreased slightly during the drier months when there were slightly higher numbers of Ae. luteocephalus especially in September and October. Aedes apicoargenteus occurred within the end of June and August in very low numbers as did most of the Culex species. Toxorhynchites brevipalpis occurred in every tree-hole throughout the period of observation with the highest percentage occurring in August and September.

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In August as many as 17, 1st and 2nd instars of Toxorhynchites brevipalpis were recorded from one sample (see Appendix 5). In T.H.2 Ae. aegypti occurred in every month in high proportions except in July and September where higher numbers of Ae. luteocephalus and Ae. stokesi were recorded. Few Culex species were recorded and Toxorhynchites brevipalpis was recorded only twice.

T.H.3 and T.H.4 were dominated predominantly by Ae. aegypti. T.H.5 also had seven different species recorded with two Culex species being very significant, C. horridus and C. pruinia. In the earlier months more Ae. aegypti was recorded than in the latter months where there was an increase in numbers of Ae. stokesi and Ae. luteocephalus. In November and in December Culex species seemed to invade the hole. Toxorhynchites brevipalpis was only recorded once. Aedes simpsoni and Aedes dendrophilus were also recorded here but this was only in December.

Observations of T.H.6 started very late in the year, but here again Ae. aegypti was the predominant species here. An Anopheles species was also recorded once.

146.

A graphical representation of the average numbers (in a sample) of mosquitoes present during the study period is given in Fig. 12. From this, seasonal variation is clearly seen. An increase in the numbers of Tox. brevipalpis in August in T.H.1 for example shows a decrease of numbers of all other mosquito species present. The decrease in numbers of Ae. aegypti towards the end of the year and the increase of Ae. luteocephalus is also shown.

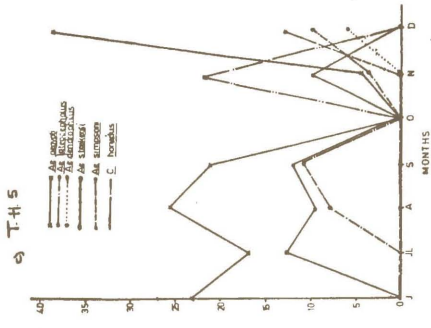
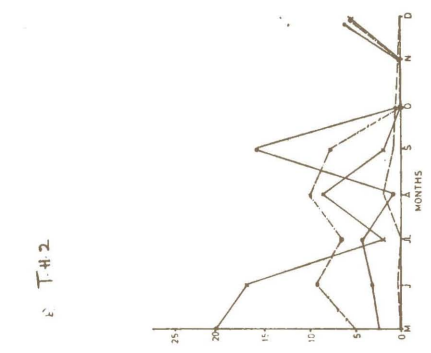
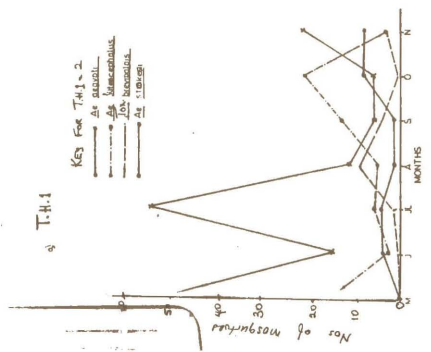
In T.H.2. Ae. aegypti is seen to decrease in numbers towards the end of the year whilst Ae. stokesi increases. Ae. luteocephalus maintains a somewhat constant population throughout the wet months.

T.H.5 shows the appearance and or succession of certain species for only particular months eg. C. horridus Ae. dendrophilus and Ae. simpsoni. Ae. aegypti and Ae. stokesi maintain a high population during the wet months.

#### 4.3.2 . Ovitraps

Table 25 list the different species encountered and the proportions of each in the total number of samples collected from the tin cans irrespective of the tree species they were attached to .

... mosquito species ...  
 ... May - December ...  
 ...



148.

Table 25

Percentages of different species of mosquitoes collected from the Ovitrap (experimental tin cans).

| Mosquito species                                      | Percentage % |
|---|--------------|
| <u>Aedes</u> <u>Stegomyia</u> <u>aegypti</u> ..       | 51.8         |
| "                              " <u>luteocephalus</u> | 23.6         |
| "                              " <u>simpsoni</u> ..   | 10.9         |
| "                              " <u>unilineatus</u>   | 2.5          |
| " <u>Aedimorphus</u> <u>stokesi</u> ..                | 3.0          |
| Culex <u>pruina</u> ..                                | 3.0          |
| " <u>decens</u> ..                                    | 2.0          |
| <u>Toxorhynchites</u> <u>brevipalpis</u> ..           |              |

Most of the species reported here also occurred in the tree-holes. Ae. aegypti was the most frequently encountered species here too, followed by Ae. luteocephalus and Ae. simpsoni. A species recorded here and not in the tree-holes is Ae. unilineatus although it is known to occur in tree-holes.

Table 26 shows that the highest number of different species were collected in July and then in November and Ae. unilineatus was only recorded for November.

149.

Table 26

Monthly distribution of numbers of different species of mosquitoes collected in tin cans (Ovitrap).

|        | <u>Ae.</u><br><u>aegypti</u> | <u>Ae.</u><br><u>simpsoni</u> | <u>Ae.</u><br><u>luteocephalus</u> | <u>Ae.</u><br><u>stokesi</u> | <u>C.</u><br><u>pruina</u> | <u>C.</u><br><u>decens</u> | <u>Ae.</u><br><u>unilineatus</u> | <u>Tox.</u><br><u>brevipalpis</u> |
|--------|------------------------------|-------------------------------|------------------------------------|------------------------------|----------------------------|----------------------------|----------------------------------|-----------------------------------|
| July   | 58                           | 23                            | 34                                 | 6                            | 6                          | 6                          | 0                                | 0                                 |
| August | 71                           | 25                            | 22                                 | 3                            | 15                         | 0                          | 0                                | 0                                 |
| Sept.  | 109                          | 9                             | 45                                 | 10                           | 0                          | 9                          | 0                                | 0                                 |
| Oct.   | 10                           | 4                             | 12                                 | 0                            | 0                          | 0                          | 0                                | 15                                |
| Nov.   | 70                           | 0                             | 42                                 | 2                            | 2                          | 0                          | 2                                | 4                                 |
| Dec.   | 60                           | 18                            | 15                                 | 0                            | 0                          | 0                          | 0                                | 2                                 |

The highest number of Tox brevivalpis occurred in October and consequently there was a reduction of all other species recorded in that month. Both Ae. aegypti and Ae. luteocephalus occurred in all months except in November. Tox. brevivalpis occurred in the three latter months.

Table 27 shows an overall distribution of species found in specific trees regardless of months in which they were found breeding.

O.T.2, O.T.3, O.T.5 exhibited the widest variety of species (7) but Ae. stokesi occurred only in O.T.3 whilst C. decens was found in O.T.5, O.T.1 and O.T.9 had the fewest species recorded.

Highest number of Tox. brevivalpis was recorded in O.T.2 and O.T.5. Ae. unilineatus was only recorded in O.T.5 and O.T.3. Ae. stokesi was only recorded in O.T.3 and O.T.7. C. pruina was the most common and most frequently encountered Culex sp and was reported in 5 different tree-holes.

A monthly analysis of the various trees (see Appendix 7) shows that in July most of the cans that were on trees that had Ae. aegypti breeding in them also had Ae. luteocephalus,

151.

but in August Ae. simpsoni seemed to replace Ae. luteocephalus. Most C. decens were collected from O.T.4 and O.T.5 in September and also the largest number of Ae. aegypti was recorded in O.T.2.

October showed the succession of Toxorhynchites brevipalpis and the highest number recorded from one tin was 6 from O.T.6. Highest numbers of Ae. aegypti were recorded in O.T.5 and from this ovitrap Ae. unilineatus was also found breeding there. General seasonality as shown in Fig. 13 stresses the fact that Ae. aegypti was the most abundant species during the observational period. Ae. luteocephalus maintains its population whilst Ae. simpsoni and Ae. stokesi populations decrease in the latter months. In all cases the appearance of the predator Tox. brevipalpis reduces the population of all other mosquito species breeding in these tin cans.

Table 28 shows frequency of encounter for the different species during the experimental time. There were quite a few occasions when these tins had been emptied or knocked down by other people and this sometimes affected the number of samples. The chart is however explanatory.

152.

Table 27

Distribution of different species of mosquitoes and trees on which tin cans were placed (Total populations)

| No.   | Tree species           | <u>Ae. aegypti</u> | <u>Ae. simpsoni</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. unilineatus</u> | <u>C. pruina</u> | <u>C. decens</u> | <u>Tox. brevipalpis</u> |
|-------|------------------------|--------------------|---------------------|--------------------------|--------------------|------------------------|------------------|------------------|-------------------------|
| O.T.5 | <u>Citrus sp.</u>      | 109                | 3                   | 4                        | -                  | 20                     | 1                | 11               | 4                       |
| O.T.1 | <u>S. saman</u>        | 39                 | 10                  | 33                       | -                  | -                      | -                | -                | 1                       |
| O.T.4 | <u>A. indica</u>       | 27                 | -                   | 10                       | 2                  | -                      | -                | 9                | 3                       |
| O.T.2 | <u>D. regia</u>        | 52                 | 4                   | 22                       | 10                 | -                      | 2                | 5                | 7                       |
| O.T.3 | <u>M. indica</u>       | 29                 | 30                  | 19                       | 2                  | 2                      | 5                | -                | 6                       |
| O.T.6 | <u>E. guineensis</u>   | 33                 | 19                  | 8                        | -                  | -                      | 3                | -                | -                       |
| O.T.9 | Grass                  | 46                 | 19                  | -                        | -                  | -                      | -                | -                | -                       |
| O.T.7 | <u>*F. platyphylla</u> | 47                 | -                   | 27                       | 9                  | -                      | 9                | -                | -                       |
| O.T.8 | <u>*Musa sp.</u>       | 3                  | 4                   | 9                        | -                  | -                      | -                | -                | -                       |

\* Sampled for only 2 months each.

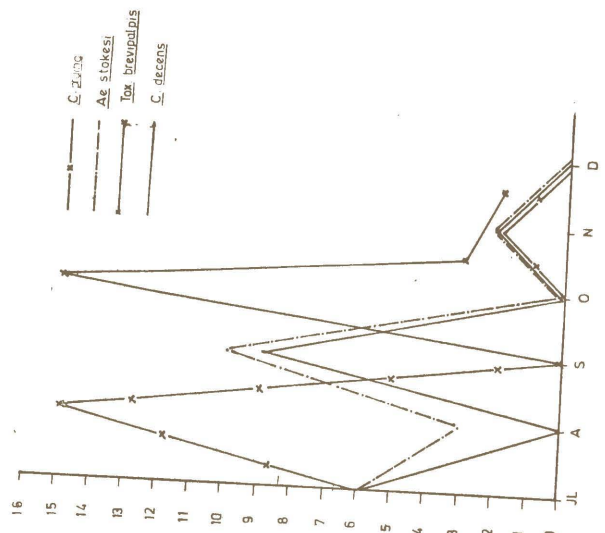
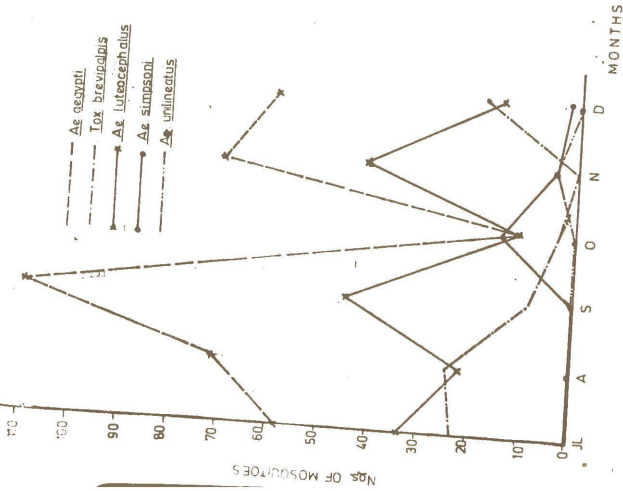
Table 28

University of Ghana <http://ugspace.ug.edu.gh>  
 Frequency of occurrence of different mosquito species  
 in the experimental tree sites (tin cans)

|       | Tree species          | <u>Ae. aegypti</u> | <u>Ae. simpsoni</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. unilineatus</u> | <u>C. pruina</u> | <u>C. decens</u> | <u>Tox. brevipes</u> |
|-------|-----------------------|--------------------|---------------------|--------------------------|--------------------|------------------------|------------------|------------------|----------------------|
| O.T.5 | <u>Citrus sp.</u>     | 14                 | 3                   | 5                        | 0                  | 4                      | 2                | 1                | 1                    |
| O.T.1 | <u>S. saman</u>       | 10                 | 2                   | 10                       | -                  | -                      | -                | -                | 1                    |
| O.T.4 | <u>A. indica</u>      | 9                  | -                   | 3                        | 1                  | -                      | -                | 4                | 1                    |
| O.T.2 | <u>D. regia</u>       | 10                 | 2                   | 8                        | 2                  | -                      | -                | 2                | 3                    |
| O.T.3 | <u>M. indica</u>      | 8                  | 6                   | 4                        | 1                  | 1                      | 2                | 1                | 3                    |
| O.T.6 | <u>E. guineensis</u>  | 8                  | 4                   | 2                        | -                  | -                      | 2                | -                | -                    |
| O.T.9 | Grass sp              | 12                 | 4                   | -                        | -                  | -                      | -                | -                | -                    |
| O.T.7 | <u>F. platyphylla</u> | 8                  | -                   | 4                        | 4                  | -                      | 4                | -                | -                    |
| O.T.8 | <u>Musa sp</u>        | 2                  | 2                   | 4                        | -                  | -                      | -                | -                | -                    |

No. of samples = 18

FIG. 12. AVERAGE NUMBERS OF SPECIES CAJ... 1 JUL-1961



4.3.3 Clay pots

The mosquito species and the frequency of their occurrence from the two earthenware pots placed near the Zoology Department are shown in Table 29.

Table 29.

The incidence of the different species of mosquitoes breeding in clay pots

| Mosquito species                                    | Percentage % |
|---|--------------|
| <u>Culex</u> ( <u>Lutzia</u> ) <u>tigripes</u> ..   | 53.0         |
| <u>Toxorhynchites</u> <u>brevipalpis</u> ..         | 23.0         |
| <u>Culex</u> ( <u>Culex</u> ) <u>duttoni</u> ..     | 11.0         |
| <u>Culex</u> ( <u>Culex</u> ) <u>decens</u> ..      | 3.2          |
| " " <u>pruina</u> ..                                | 1.5          |
| <u>Aedes</u> ( <u>Stegomyia</u> ) <u>aegypti</u> .. | 7.0          |
| " " <u>vittatus</u> ..                              | 1.0          |

Most of these species kept on recurring during the entire observational period but it was only Ae. vittatus which was noticed to breed only in January.

4.3.4 Dried debris

Eggs that hatched from the dried debris collected were of the species listed below. These observations were made in October.

In tree-hole 2, Ae. aegypti (75%) formed the largest percentage followed by Ae. stokesi (15%) and Ae. luteocephalus (10%).

From tree-hole 5 only Ae. luteocephalus 80% and Ae. aegypti 20% were recorded.

There was more organic matter collected from Tree-hole 5 than Tree-hole 2 which had plenty of sand in it.

4.4      DISCUSSION

Ecological studies of tree-holes are difficult. Although they support a wide range of mosquito species, tree-holes are small habitats and often only temporary. They are dependent on the external climatic conditions as adequate rains are required to fill them and thus initiate breeding.

Dunn (1972b) points out that tree-holes are usually a result of human damage to the trees and are found more frequently in trees that are near human settlements than in uncultivated areas.

Although there is a wide range of trees on the University campus most of them are ornamentals and had not been tampered with by man or were too young to have formed holes of an appreciable size. The only tree species which frequently had holes was Delonix regia and this however seems to be characteristic of its mode of growth. There was one particular tree that had about 15 holes on it.

Aedes aegypti is originally a tree-hole breeder as pointed out by Soper (1967), Garnham et. al. (1946), Surtees (1959), but easily becomes adapted to a domestic way of life as seen by Christophers (1960) MacDonald (1956).

Garnham's et.al (1946) observations in Kaimosi forest of Kenya showed that in its natural habitat in the forests Ae. aegypti never breeds in domestic containers. He also observed that Ae. aegypti breeds in a wide variety of places and showed that even in the forests, tree-holes were not necessarily the most favoured places as he reports of their breeding equally well in rock pools, tree stumps and pools by the river bed.

The formation of tree-holes is discussed extensively by Dunn (1927b), and Kitching (1971a) and since they are mainly under the influence of man they vary very much in their size and location on <sup>the</sup> tree. But in most cases they are filled with humus and other forms of debris and as such with time they retain water which eventually goes foul. In a domestic situation Ae. aegypti is reported to breed only in clean water and is not able to tolerate any degree of contamination. Surtees (1960b) however states that Ae. aegypti has a great tolerance for dirty water. Garnham et.al (1946) observed that conditions like height, shade, shape and size of the tree-hole play a more important role in determining the selection of breeding places than the actual composition of the water. Similarly in the present observations Ae. aegypti was found along with other species in extremely foul ~~water~~.

Extensive research has been carried out in other parts of West Africa and reports indicate that a large range of trees do have holes which can support larval populations during the wet months. It was therefore decided to create artificial 'holes' on some of these trees in our study area e.g. Mangifera indica and hence the observations in the tin cans (ovitraps). These were also appropriate as observations could be carried out into the dry season.

A total of 11 species were recorded in both the tree-holes and the artificial tree-holes (tin cans). In both types of containers, Ae. aegypti was the most frequently encountered species and had the highest density too. Macfie and Ingram (1916) in surveys in Accra showed relatively the same proportion of the species found i.e. Ae. aegypti was 88% of all the samples whereas the other Aedes and Culex species had much lower percentages. They however did not restrict themselves to tree-holes. In the present study Ae. aegypti formed 63% of all the samples found in the tree-holes and 51% of those collected in tin cans. These percentages are lower than those of Macfie and Ingram (1916) but all the same show dominance of Ae. aegypti over the other domestic species.

160.

In both cases Ae. luteocephalus followed next in density and frequency. Although Hopkins (1952) reports that this species occurred less commonly in domestic utensils it appears that it plays a significant role in the total numbers caught in the tin cans.

Aedes stokesi has not been reported of much in Ghana, as often as in Nigeria (Service 1963; 1965), Dunn (1927) and Hanney (1960). It occurs in small numbers in the tin cans and formed only 2.9% of the total collections. It however was able to breed in larger numbers in the tree-holes(8%).

Ae. stokesi seemed to occur significantly in T.H.5 (P. pterocarpum) but it was not restricted there. It is noticed that Ae. stokesi was found mainly in tree-holes that had <sup>a</sup> large surface area and retained water for a long time.

Ae. apicoargenteus and Ae. dendrophilus have both been recorded breeding in tree-holes and in decaying banana fibre by Macfie and Ingram (1922). They always however formed a small percentage of the total population.

Ae. unilineatus was only recorded in the tin cans in this research although it is known to breed extensively in tree-holes. In fact Macfie and Ingram (1922) reported it from a Flamboyant tree. It is difficult to tell why it has

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not occurred in these collections. It is probably seasonal.

Ae. simpsoni occurred here both in the tin cans and the tree-holes. This species, although it has been reported a few times in tree-holes, is characteristic for being collected from plant axils (Peterson and Lambrecht, 1976).

Culex species observed in tree-holes and tin cans for both groups are very similar although C. decens seems to be more frequent in tree-holes whereas C. pruina breeds more in the tin cans.

Tox. brevipalpis was found in both the tree-holes and tin cans but it is noticed that numbers and frequency of Tox. brevipalpis increased in October in the tin cans, as most of the tree-holes had dried<sup>up</sup> and these tin cans therefore act as an alternate habitat. Service (1965) wondered how Tox. brevipalpis survived the dry season as other species had aestivate. This therefore suggests that Tox. brevipalpis looks for alternative breeding sites to survive unfavourable weather.

It is difficult to point out any definite seasonal variation in these species as the collections were only a short period and in some cases tree-holes were filled with

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water to continue the cycles to obtain results. Ae. aegypti, we can conclude, is ubiquitous and can be found all year round although numbers decrease slightly in the dry season. Although numbers fluctuated in tin cans, the trend was more or less similar. The problem was however, people removed the cans or emptied them and as such a few results were affected.

With certain trees, T.H.2 and T.H.1 the numbers of Ae. luteocephalus increased in the dry season. There was a sudden appearance of Ae. dendrophilus in October and November in the cans and of C. horridus in T.H.5. Culex decens disappeared entirely in the dry season. There is also a switch from tree-hole breeding to tin cans in the dry season for Tox. brevipalpis. But apart from these observations it is difficult to draw up any definite succession or replacement of one species by another.

Macfie and Ingram (1916) were able to suggest that the incidence of mosquitoes does not depend on the climate but that was because they were collecting samples from water made available by man (i.e. bad drainage). But in the present case, rainfall and temperature play a vital role in determining the different mosquitoes in the area as these breed in tree-holes which are not filled by man.

That certain species of trees attract particular species of mosquitoes is a point that has been discussed at length by many authorities and Taylor (1934) concludes that there is no evidence to prove that mosquitoes showed preference in selection of a tree for oviposition. To be able to obtain definite results it would be important to carry out these investigations for a very long time. With the tin cans no special height was maintained as they were placed at random. For example, the tins on the Citrus tree (OT5) and on Samanea saman were both above 1.7m and that of Mangifera indica (OT3) were relatively low. Yet the Citrus sp. Delonix regia, and M. indica attracted the largest number of different species, and the only similarity was that these trees had heavy undergrowths of grass and other shrubs. It can however be pointed out that the height of holes may have an influence on the inhabitants. Tin cans placed at a height of 1 - 1½m of the ground had the widest range of mosquito species breeding in them. Tins placed on the ground rarely had Culex species breeding in them and were dominated by Ae. aegypti, Ae. luteocephalus and Ae. simpsoni. A height of 2m is difficult to assess because whilst OT8, Musa sp. had the fewest inhabitant, O.T.1, S. saman had Ae. luteocephalus and Ae. aegypti only breeding in it.

Tree-holes T.H.1 and T.H.5 were of the same size and had similar shapes. Both harboured the largest number of different species. They had similar Aedes species breeding and T.H.5 was different in having Ae. simpsoni in addition to a wider variety of Culex species. Tree-holes 3, 4 and 6 were all Flamboyant trees (Delonix regia). Tree-holes 3 and 4 were both very small and had mainly Ae. aegypti and Ae. luteocephalus whilst T.H.6 was much larger and had a few more species. It would appear however that the size of the hole is more important than the species of the tree. Chapman and Ferrigno (1956) concludes that 'The prevalence of Aedes depends more on the amount of water present than the type of vegetation'. It was also noticed that there was some similarity between the species breeding in the tin can placed in the Flamboyant tree and the actual T.H.6 which is also a similar species.

Although few samples were taken from clay pots, two other Culex species were observed and they are Culex tigris and Culex duttoni. Ae. aegypti was recorded but in very low numbers as it was persistently being preyed on both <sup>by</sup> Tox. brevipalpis and C. tigris. It was noticed that in the absence of Ae. aegypti other species that breed in the clay pots for example C. decens and C. pruina were eaten. These

two predators dominated the clay pots all the time.

On soaking the dry debris only three species of Aedes were recorded: Ae. aegypti, Ae. stokesi, Ae. luteocephalus; Several other species have been recorded by other workers (Dunn 1926; Service 1965; Trips 1927; Lambrecht and Peterson, 1976).

That tree-holes play a major part in providing a source of habitat for many mosquitoes cannot be overemphasised as shown by these observations. So long as there is water in them they can support many larvae as apart from other predeceous mosquitoes no predators were encountered, although several other beetles were seen.

Since several authorities have decided that their presence is negligible they often go unnoticed whereas in reality they could contribute tremendously to the numbers of mosquitoes in an area, and more attention should be paid to them during mosquito eradication/control campaigns.

PART II

4.5 A 15 MONTH SURVEY OF AEADES AEGYPTI BREEDING IN  
TWO VILLAGES SHOWING POPULATION INDICES  
AND SEASONAL INCIDENCES

4.5.1 Introduction

Although no yellow fever epidemic has been reported in the south-eastern section of Ghana, it is always possible that an epidemic can break out since certain portions of Ghana have been declared endemic (Mouchet, 1971) and mosquito breeding in peridomestic water containers is evident there.

A look at the 10 year Epidemiology report of the Ministry of Health (1981) (see Chapter 1) shows that the mass immunization programmes carried out in 1969/70 and 1977/79 concentrated mainly on the areas where previous outbreaks had occurred and the Greater Accra region for example was left out. The proximity of these regions e.g. Volta and the regular traffic of people suggests that the risk of its introduction to such areas where water is stored is very high. Therefore to assess whether infection could become established in this part, a larval survey was carried out in two villages, Amasaman and Danfa in the Greater Accra region.

The vector Ae. aegypti, has been subjected to several methods of assessing and predicting its population densities and as Tinker (1967) pointed out "it is very essential in planning and eradication programmes to be able to evaluate procedures to understand the characteristics of the possible population measurements".

Extensive surveys have been carried out in different parts of the world. In Asia, Macdonald (1956) carried out a research and in conjunction with Rajapaksa (1972) another survey in Borneo. Sheppard et.al. (1969) conducted a study in Thailand and Chan et.al. (1971a, b) in Singapore. In these areas the surveys were to evaluate the role of the vector and other Aedes species in the epidemiology of dengue haemorrhagic fever. Tonn and Bang (1971) and Tonn et.al. (1969) worked in Thailand, Soper et. al. (1943) in Brazil and Tinker (1959) in the United States of America.

In Africa notable surveys are those carried out in Tanzania by Rao (1973); Pichon and Gayral (1970) in Upper Volta and in Nigeria surveys by Surtees (1959) and Service (1974) who after the last major epidemic in 1968/69 on the Jos Plateau attempts to provide data showing the importance of Aedes species as transmitters of Yellow fever in Northern Nigeria. It is noted that the time period coincides with the last but one major epidemic in the Northern part of Ghana.

Chinery (1969) and Mouchet (1971) both carried out surveys in Ghana in the Southern and Northern regions respectively. Chinery's (1969) two Year Survey was in Accra and in Tema and was directed at evaluating the different species breeding, their density and preferred breeding sites in order to effect adequate larval control. He also discusses seasonal variation. Mouchet (1971), a W.H.O. consultant studied the density and distribution of potential Yellow fever vectors and their relation to man and their effectiveness as carriers, after the first major epidemic in the Northern region of Ghana.

#### 4.5.1.1 Aedes aegypti larval indices

Several indices have been defined and compared by different workers but in all cases they enable the population density of Ae. aegypti breeding in a particular area to be expressed as a relative measurement. These indices provide a basis for comparison between different areas or different seasons in the same area, or different areas in a particular season.

The survey itself comprises of collections of larvae from different breeding sites in an area and the indices so far used in expressing population densities are (Service 1976):-

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- 1) House (= Premise) Index - The percentages of houses and surrounding compounds that have larvae of Ae. aegypti in at least some containers.
- 2) Container (= Receptacle) Index - The percentage of water holding containers that contain larvae of Ae. aegypti
- 3) Breteau Index - total number of containers with larvae of Ae. aegypti per 100 houses.
- 4) Density Figure (Index) - an arbitrary scale of 1-9 which allows the different indices to be compared and correlated (Brown 1973).

Tinker (1967) includes the following:-

- 5) Block index - The percentage of inspected blocks that are infested.
- 6) The infested receptacle index - Is the average number of infested receptacles per inspected premises.

Chan et.al (1971) include:-

- 7) Larval density index - The average number of larvae per housing unit in an area, i.e. a measure of density.

Soper (1943) adds:-

- 8) The Ae. aegypti index - The percentage of houses with evidence of the breeding of the vector.

Most of the indices were calculated except the block index which is not applicable here but is very useful in

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control campaigns in the U.S.A. where areas are divided into blocks to facilitate spraying.

To a large extent the indices will vary due to the different habits of the ethnic groups, and to the climate and the availability of breeding places.

A review of past surveys shows that the House Index has been the most widely used and is very reliable as it is the least variable and depends least on the interpretation of the inspector (Tinker, 1967).

The choice of index is of utmost importance if results are to be useful. However a good positive correlation exists between most of these indices (Service 1976) the best being between the House and the Block indices and therefore if one index is obtained the others can all be closely approximated. Besides, these two indices are the most efficient as less data is collected and handled in their calculation and can be used to locate areas with unusual (either very high or very low) Ae. aegypti populations.

Chan et.al. (1971b) found a good relationship between the larval density index and the House and Infested receptacle indices. This larval density index was actually introduced to

compare Aedes populations between different areas and times.

For practical purposes the infested receptacles index is the most useful and convenient as it gives a more exact expression of Ae. aegypti populations but is greatly affected by a few premises with large numbers of breeding receptacles. Tinker (1967) however found it less accurate as there were large deviations.

The W.H.O. (Anon. 1973) tabulated the density figure 1-9 which is based primarily on the 3 principal larval indices (House, Container and Breteau). This enabled a conversion table to be derived.

A density figure of above 5 is taken to indicate that the population size of Ae. aegypti has reached a level which presents a threat of urban transmission of yellow fever. Service (1974) notes that in certain parts of West Africa high indices values have been recorded without there necessarily having been an epidemic.

#### 4.6 Survey Methods

Two main methods were employed in assessing variations in peridomestic breeding, one laying emphasis on density and the other for obtaining data for calculating population indices (the single larva method, Sheppard et.al 1969).

Since both villages were not too densely populated it was decided to sample at random every third house starting from different parts of the village on subsequent sampling dates. Since a 15 month study was proposed it was decided to sample each village twice a month to be able to obtain some information on seasonal variations.

In establishing the indices the term "House" was taken to include all the buildings or rooms occupied by one family. Most of the houses formed a compound and there were different numbers of families occupying one compound. It is essential to make this division as most families differed in the number of pots they possessed and the times of fetching water or cleaning out their pots or the rate at which water was used (i.e. depending on the number of inhabitants). Even within the same compound individual families strictly adhered to their own pots and seldomly used water belonging to others. Mouchet (1971) in his survey in Northern Ghana stresses that the term house is obviously a vague and unsatisfactory term but it does represent units of comparable size. Macdonald (1956) on the other hand in a survey in Malaya decided that unless a house was clearly divided into 2 parts or more it was treated as one habitation despite the number of families occupying it. So ideally the column number of houses should read number of families but the former is retained as being more standardized

(Service 1976). These water containers were located at various parts of the house and were either metal drums holding about 200 litres or cement vats with a capacity of about 400 litres. These are not moved but filled with water from the reservoirs with smaller containers or by rain water collected by little gutters attached to the eaves of the roof (see Plate 8). Other types of containers were made of plastic, earthenware or enamel which could hold up to 100 litres. It was decided that any container outside a room was labelled as being 'outside' whether it was on the verandah i.e. under a roof or in the yard. Anything else was termed inside and actually not too many containers were kept inside as most people had mainly metal drums only. Those containers kept inside were normally covered with a tightly <sup>fitting</sup> lid and used only for drinking. These were often inaccessible as sampling was done at a time when most people had gone to farm or work. Containers that were kept in the kitchen of some of these houses posed a problem as most of these kitchens had no doors but by our set definition still fall under 'inside containers'.

At Danfa the local distillery had lots of metal barrels which were used for brewing local gin; these were not included in the survey as they might give a wrong impression considering that the brewery was quite far from the town and



Plate 8: A mud house at Amasaman showing the different types of water receptacles. The guttering allows rain water to fall directly into the jars during a rain storm.

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many Culicines not necessarily Aedes sp. were found e.g. C. decens.

At Amasaman there were a few old tyres at the tractor assembly plant but since most times they were dry and the factory was a considerable distance from the village they were not included. Both towns were relatively clean and there were few broken bottles, coconut shells, or empty tins around and the occasional ones were also ignored as erroneous results may be obtained.

At each compound the number of families and the total number of containers were recorded and their position i.e. in or outside, covered or not and whether there was any water in them or not. The receptacles were then inspected to look for evidence of mosquito breeding. The numbers of positive containers were recorded and a single larva was taken from each and put in a labelled bottle. Then from each infested receptacle 3 dips using a three inch square bowl was made and the larvae put into another container, and from this container an idea of density can be calculated.

Next, other associated species were recorded and put into another container to be taken to the laboratory for identification. Any other peculiarity was noted; for example there was a day at Amasaman that most pots were empty

as the people were expecting rain, that will automatically reduce positive infestation records, (see appendix 10).

#### 4.7 RESULTS

##### 4.7.1 Population Indices

Tables 30 and 31 show calculated W.H.O. indices (House, Container, Breteau, Infested receptacle and larval density) as obtained from a 15 month study in Danfa and Amasaman respectively. Aedes aegypti was recorded all year round in both villages with Danfa showing a higher prevalence.

Density figures for the two areas indicate that Danfa has a higher potential for the transmission of yellow fever because in more months (January, March, April, May, July) a density figure of 5 or above was recorded.

Populations of Ae. aegypti at Amasaman were much lower and a density figure of 5 was only recorded once and that was in May.

This finding is also reflected in the larval density figure index which shows Danfa having a higher density with a mean of 10.18, ranging from 2.57 recorded in June to 22.42 recorded in May. Generally it was observed that the wetter months of the year had higher larval densities. Amasaman had an average of 5.56 with a range of 1.01

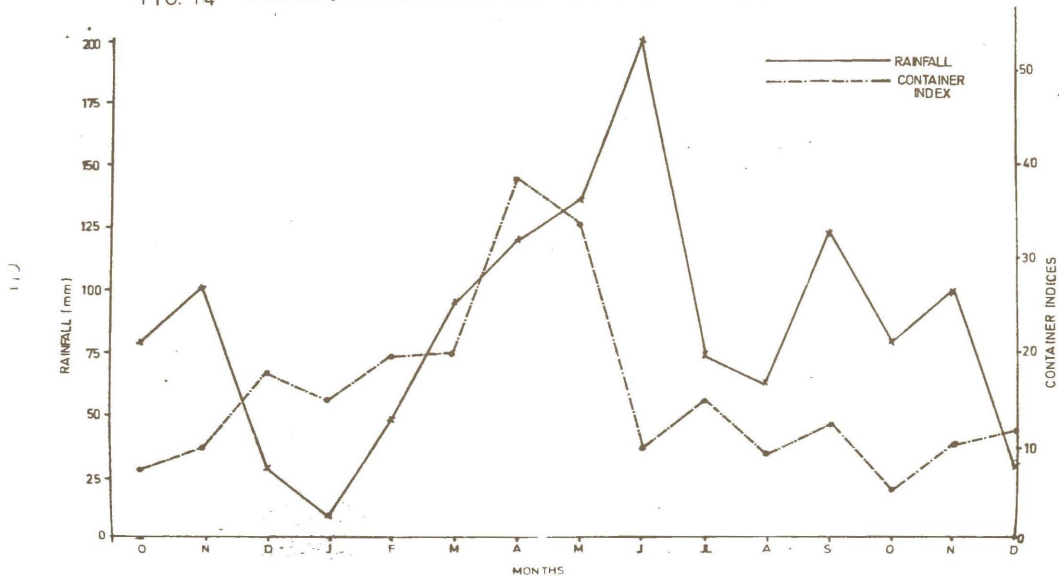
Table 30

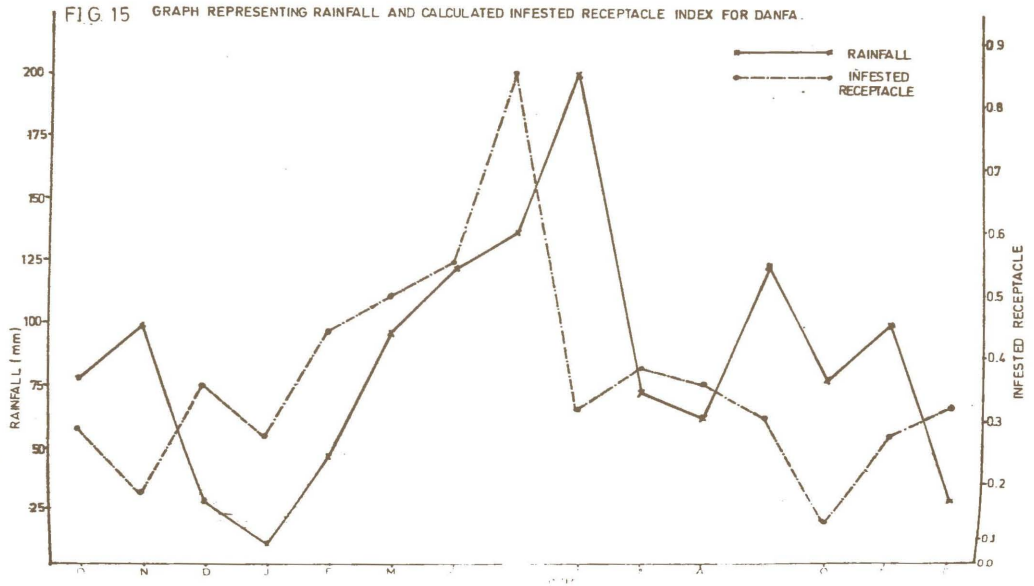
## CALCULATED W.H.O. INDICES FOR AE: AEGYPTI POPULATION AT DANFA

|      | Larval Density Index | House Index    | Container Index | Breteau Index   | Infested receptacle Index | Density Figure | Other Insect Species Recorded   |
|------|----------------------|----------------|-----------------|-----------------|---------------------------|----------------|---|
| 980  | 5.31<br>4.98         | 10.25<br>13.45 | 7.24<br>8.56    | 12.22<br>16.00  | 0.26<br>0.30              | 3<br>3         | <u>C. decens</u><br><u>C. tigripes</u>                                |
| ov.  | 3.95<br>5.63         | 14.28<br>13.26 | 11.53<br>8.42   | 14.28<br>16.30  | 0.142<br>0.223            | 3<br>3         | <u>C. decens</u><br><u>Hemipteran sp.</u>                             |
| ec.  | 8.51<br>10.32        | 24.24<br>23.46 | 20.40<br>16.11  | 30.00<br>32.12  | 0.303<br>0.40             | 4<br>4         | <u>C. tigripes</u>  |
| 1981 | 13.2<br>12.24        | 12.12<br>32.00 | 8.16<br>22.64   | 12.12<br>48.00  | 0.121<br>0.48             | 3<br>6         | <u>C. duttoni</u><br><u>Odonata nymphs</u>                            |
| eb.  | 9.4<br>12.5          | 24.00<br>25.00 | 17.24<br>20.96  | 40.00<br>46.42  | 0.40<br>0.46              | 4<br>4         | <u>C. duttoni</u><br><u>C. tigripes</u>                               |
| ar.  | 17.93<br>8.74        | 46.00<br>19.35 | 27.00<br>12.7   | 66.00<br>35.04  | 0.66<br>0.35              | 6<br>4         | <u>C. decens, C. duttoni</u><br><u>Odonata nymph</u>                  |
| or.  | 17.96<br>12.45       | 39.39<br>23.52 | 36.66<br>41.02  | 66.66<br>47.05  | 0.66<br>0.45              | 6<br>4         | <u>C. duttoni</u><br><u>C. tigripes</u>                               |
| ty   | 16.02<br>22.42       | 32.35<br>50.00 | 38.23<br>25.39  | 76.47<br>100.00 | 0.764<br>1.00             | 6<br>7         | <u>C. duttoni</u><br><u>Coleoptera &amp; Hemiptera</u><br>— predators |
| ne   | 2.57<br>110.38       | 3.84<br>25.80  | 3.38<br>12.56   | 70.00<br>38.70  | 0.07<br>0.301             | 1<br>4         | <u>C. tigripes</u><br><u>C. duttoni</u>                               |

|      | Larval<br>Density<br>Index | House<br>Index | Container<br>Index | Breteau<br>Index | Infested<br>receptacle<br>Index | Density<br>Figure | Other Insect<br>Species Recorded  |
|------|----------------------------|----------------|--------------------|------------------|---------------------------------|-------------------|---|
|      | 16.41                      | 34.78          | 17.91              | 52.17            | 0.521                           | 5 5               | <u>C. duttoni</u>   |
|      | 8.28                       | 19.56          | 12.50              | 23.40            | 0.347                           | 4 4               | <u>C. tigripes</u>  |
|      | 7.30                       | 15.38          | 10.76              | 26.92            | 0.53                            | 3 3               | <u>C. duttoni</u>   |
|      | 9.45                       | 22.72          | 8.95               | 27.27            | 0.272                           | 4 4               | <u>C. tigripes</u> <u>Odonata</u><br>nymphs   |
|      | 3.40                       | 16.00          | 12.19              | 2.00             | 0.20                            | 3                 | <u>C. decens</u>  |
|      | 10.66                      | 16.60          | 14.92              | 41.66            | 0.416                           | 3                 | <u>C. tigripes</u> <u>Odonata</u><br><u>C. duttoni</u> nymphs                         |
| Oct. | 3.66                       | 9.52           | 3.17               | 9.52             | 0.095                           | 3                 | <u>C. decens</u>  |
|      | 4.00                       | 7.14           | 8.82               | 21.42            | 9.214                           | 3                 | <u>C. pruina</u> , <u>C. tigripes</u><br><u>C. duttoni</u> , <u>Odonata</u><br>nymphs |
| Nov. | 18.31                      | 18.18          | 10.00              | 24.24            | 0.242                           | 4                 | <u>C. duttoni</u> , <u>C. tigripes</u>  |
|      | 13.85                      | 20.12          | 12.63              | 28.10            | 0.31                            | 4                 | <u>Odonata</u> nymphs   |
| Dec. | 10.93                      | 18.75          | 12.98              | 31.12            | 0.412                           | 4                 | <u>C. duttoni</u> , <u>C. tigripes</u>  |
|      | 12.00                      | 23.10          | 13.60              | 31.00            | 0.412                           | 4                 |   |

FIG. 14 RAINFALL (10yr. AVERAGE) COMPARED TO CONTAINER INDEX VALUES FOR DANFA





(August) to 12.18 recorded in June.

A mean of  $30.06 \pm 7.54$  houses were sampled every week at Amasaman and  $30.04 \pm 5.71$  from Danfa. More water storage containers were observed per house at Danfa, a mean of  $2.24 \pm 0.556$ , than at Amasaman ( $1.89 \pm 0.27$ ). In both villages these values were of receptacles outside as inside pots were very few and invariably inaccessible. Only about 40% of the receptacles outside at Danfa were covered and about 50% at Amasaman and in the latter village water was stored for very short periods.

Mean House index for Danfa was 21.81 (range 3.84 -46.0) and for Amasaman 15.68 (range 2.01 - 34.37) showing that Ae. aegypti had a wider distribution at Danfa than at Amasaman as more houses were infested.

At Amasaman it was noticed that the houses on the side of the road furthest away from the reservoir had more evidence of Ae. aegypti breeding; in effect Ae. aegypti breeding was more localised.

The container and infested receptacle index have been compared to rainfall in the 2 areas as shown in the Figs. 14 - 17. Values used for the graphs are the 10 year average for rainfall and for the indices an average of values for

Table 31

## CALCULATED W.H.O. INDICES FOR AEGYPTI POPULATION AT AMASAMAN

| Larval Density Index | House Index | Container Index | Breteau Index | Infested Receptacle Index | Density Figure | Other Species Recorded                     |
|----------------------|-------------|-----------------|---------------|---------------------------|----------------|--|
| 3.01                 | 6.30        | 8.00            | 8.35          | 0.21                      | 2              | <u>C. duttoni</u> , <u>C. decens</u>       |
| 5.02                 | 12.11       | 8.31            | 14.36         | 0.29                      | 3              | <u>C. duttoni</u> , <u>C. decens</u>       |
| 4.34                 | 14.28       | 13.15           | 14.28         | 0.142                     | 3              | <u>C. decens</u> <u>C. tigrisipes</u>      |
| 5.55                 | 11.21       | 9.02            | 15.61         | 0.25                      | 3              | <u>C. duttoni</u>                          |
| 5.96                 | 23.33       | 21.42           | 30.00         | 0.45                      | 4              | <u>C. decens</u>                           |
| 5.20                 | 14.70       | 17.64           | 17.64         | 0.176                     | 3              | <u>Anopheles</u> sps.                      |
| 5.97                 | 23.59       | 45.00           | 28.8          | 0.235                     | 4              | <u>C. duttoni</u> , <u>Odonata</u> nymphs  |
| 5.34                 | 20.68       | 16.6            | 31.03         | 0.310                     | 4              | <u>Hemipteran</u> predator                 |
| 8.86                 | 27.27       | 19.51           | 36.36         | 0.363                     | 4              | <u>C. duttoni</u>                          |
| 11.14                | 28.57       | 21.56           | 39.28         | 0.392                     | 4              | <u>C. tigrisipes</u>                       |
| 4.71                 | 15.6        | 9.6             | 15.6          | 0.156                     | 3              | <u>C. decens</u>                           |
| 11.06                | 19.00       | 11.00           | 25.00         | 0.25                      | 4              | <u>Odonata</u> nymphs                      |
| 5.35                 | 16.00       | 9.00            | 16.5          | 0.161                     | 3              | <u>Coleopteran</u> spp.                    |
| 5.90                 | 20.00       | 21.42           | 26.06         | 0.266                     | 4              | <u>C. duttoni</u>                          |
| 5.54                 | 20.00       | 22.72           | 27.27         | 0.272                     | 4              | <u>Tox. brevivalpis</u>                    |
| 8.46                 | 34.37       | 35.13           | 50.00         | 0.500                     | 5              | <u>C. duttoni</u><br><u>Odonata</u> nymphs |

Table 1 cont'd.

|  | Larval<br>Density<br>Index | House<br>Index | Container<br>Index | Breteau<br>Index | Infested<br>Receptacle<br>Index | Density<br>Figure | Other Species<br>Recorded                 |
|--|----------------------------|----------------|--------------------|------------------|---------------------------------|-------------------|---|
|  | 7.30                       | 18.18          | 16.08              | 30.30            | 0.303                           | 4                 | <u>C. duttoni</u> , <u>C. tigripes</u>    |
|  | 12.18                      | 27.20          | 18.5               | 45.45            | 0.454                           | 4                 | <u>C. decens</u> , <u>Odonata</u> nymph   |
|  | 7.83                       | 18.11          | 12.5               | 27.27            | 0.277                           | 4                 | <u>C. duttoni</u> ,                       |
|  | 2.57                       | 8.33           | 5.45               | 12.50            | 0.125                           | 3                 | <u>C. duttoni</u> , <u>Hemipteran</u>     |
|  | 2.44                       | 6.89           | 3.70               | 10.34            | 0.103                           | 2                 | <u>C. duttoni</u> , <u>C. tigripes</u>    |
|  | 1.01                       | 2.01           | 1.03               | 2.0              | 0.09                            | 1                 | <u>C. decens</u>                          |
|  | 2.2                        | 10.00          | 8.0                | 16.6             | 0.166                           | 3                 | <u>C. duttoni</u> , <u>Odonata</u> nymphs |
|  | 1.13                       | 4.54           | 1.92               | 4.54             | 0.043                           | 2                 | <u>C. duttoni</u> , <u>C. tigripes</u>    |
|  | 3.0                        | 9.67           | 6.89               | 12.90            | 0.129                           | 3                 | <u>C. decens</u>                          |
|  | 5.48                       | 8.00           | 5.88               | 12.00            | 0.12                            | 3                 | <u>C. decens</u> , <u>Anopheles</u> spp   |
|  | 9.43                       | 24.34          | 19.40              | 35.13            | 0.351                           | 4                 | <u>C. tigripes</u>                        |
|  | 8.53                       | 12.5           | 6.45               | 12.5             | 0.125                           | 3                 | <u>Hemipteran</u> spp                     |
|  | 5.89                       | 13.62          | 7.01               | 15.61            | 0.22                            | 3                 | <u>C. decens</u>                          |
|  | 6.45                       | 19.20          | 12.61              | 28.80            | 0.36                            | 4                 | <u>C. duttoni</u>                         |

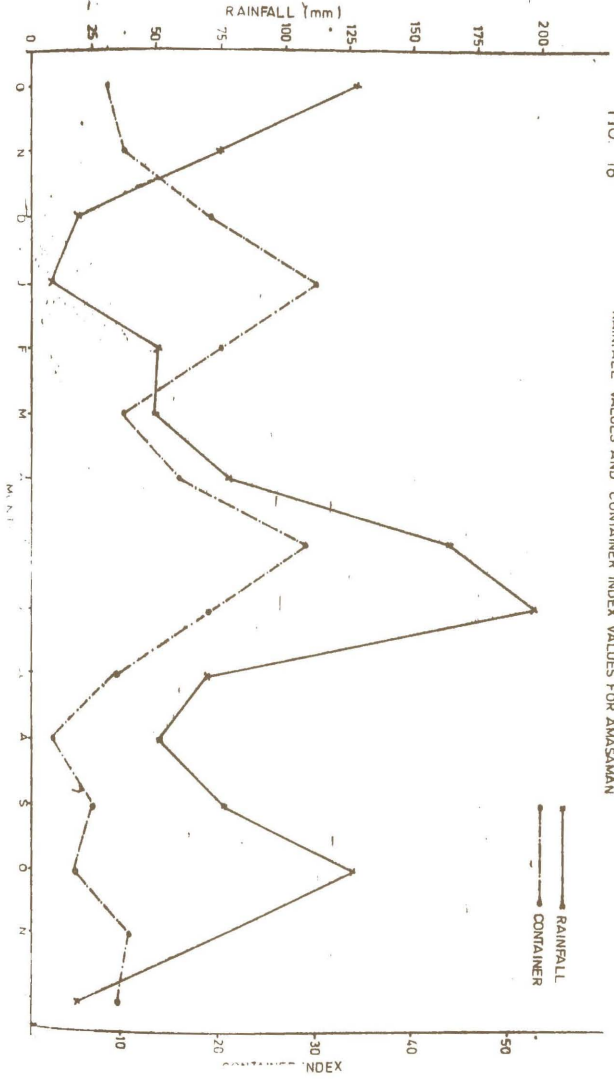
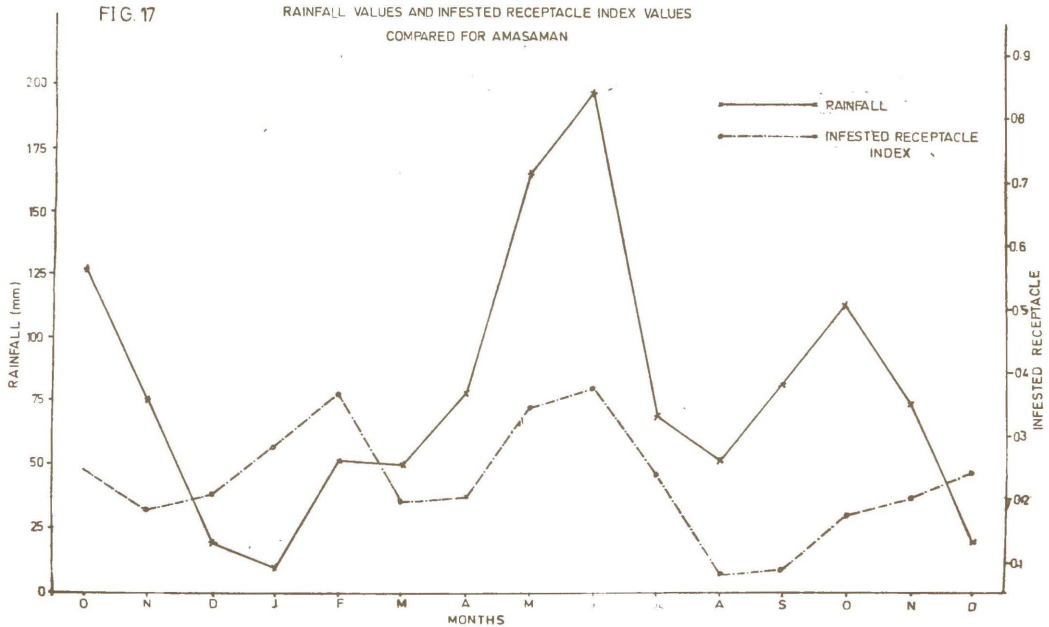


FIG. 16 RAINFALL VALUES AND CONTAINER INDEX VALUES FOR AMASAMAN

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each month. The use of average values for rainfall became necessary because the Meteorological stations have very poor records for these study areas since they were considered small stations and not much attention was paid to them. As at the time of analysing the data, values of the more recent months had not been compiled and were thus unavailable. For Danfa both indices closely approximate the rainfall pattern and they both exhibit just one peak. The infested receptacle index peaks a month before the rainfall and the container 2 months before. It is only in the drier periods of the year December-February that container and infested receptacle indices appear higher than rainfall when there is need to store more water for longer periods. Mean: for Container Index was 15.22 (range 3.38 - 38.23) and for Infested receptacle 0.375 (range 0.09 - 1.0).

Data for Amasaman, see Fig. 16, 17 are basically similar but here there are 2 peaks for the indices, one occurring in the dry season and the other in the wet season, the peaks are however not as high as that of Danfa. Mean container index is 13.81 (range 1.03 - 35.13) and that for infested receptacle 0.235 (range 0.09 - 0.50). These values again stress the higher incidence of Ae. aegypti at Danfa.

Observations show that a larger number of pots were kept in the rainy season than in the dry season; this is very obviously seen at Danfa.

Breteau indices are higher at Danfa than at Amasaman with 100.00 being recorded as the highest value there and 50 for Amasaman.

In the dry seasons of December-February, and August, there are comparably lower densities of Ae. aegypti and in the wetter months a marked increase except in a few months e.g. June which will be accounted for in the discussion.

#### 4.7.2 Larvae of Other Species

Several other mosquito species were observed breeding in these peridomestic pots, the most common being Culex duttoni. This species occurred in very large numbers especially at Danfa in July and August where their population far exceeded that of Ae. aegypti. At Amasaman although not encountered so often C. duttoni outnumbered Ae. aegypti and in August as well. Culex duttoni was found breeding all year round at Danfa. In November however, no Culex species was found breeding at Amasaman at all.

Culex decens also occurred in both villages but in much smaller numbers. Culex tigripes was reported more often in Danfa and was preying on both Ae. aegypti and C. duttoni first and second instars mainly.

Tox. brevipalpis was recorded once at Amasaman and never at Danfa. Other arthropods include Odonata larvae (mainly Brachythermis leucostica) and aquatic Coleopterans and Hemipterans and some chironomids. Tadpoles were frequently encountered as they bred in the reservoirs in large numbers and were collected by the villagers when they went to fetch water. Occasionally some small fishes were also observed in the pots.

#### 4.8 DISCUSSION

##### 4.8.1 Population Indices

This survey has shown that the South-eastern portion of the Greater Accra region cannot really be considered as extensive Ae. aegypti focus. This situation, however, is dependant on the habits of the people and can easily change if these alter and if piped water supply comes to the villages, as climatic conditions are favourable and breeding sites are abundant.

No previous surveys have been carried out in these two particular areas but surveys have been carried out by Mouchet

(1971), Chinery (1969) and Agadzi (1982), in nearby places which will be discussed later.

Aedes aegypti breeds extensively at Danfa which is of a more rural setting than Amasaman and it was noticed that the density figures obtained for Amasaman all year round were below the threshold value at which epidemics are considered to spread. As such most of the calculated W.H.O. values for Danfa are much higher than those for Amasaman.

In this survey breeding sites were limited to water holding receptacles in and around houses. This might be criticised as limiting the actual scope of breeding, but this limitation had to be used because existing tin-cans, coconut shells, flower vases and ant traps were so few that those observed would have affected results as they were mostly always empty and could hardly store enough water to support larval maturation and thus contribute to the adult population. Mouchet (1971) in his survey examined all containers and places where water had collected both inside and outside the compound and these included dumps of old tyres and scrap iron. But I do not think he used such results in calculating his indices as they are recorded separately and he stresses that it would be difficult to include these in indices designed for a domestic insect: he therefore only recorded empty jars

and drums that were in a likely position to capture rain water; thus jars for preparing beer for example were not recorded. Agadzi (1982) however did not disclose the scope of his larval collections but it is believed that he limited his research to water receptacles near houses. Chinery (1969) establishes the fact that Ae. aegypti preferred breeding in receptacles as compared to septic tanks, soakways, car parts or flower vases and therefore limited his research to those. Rao (1973), however, thinks that these small abandoned containers and tyres are not a negligible source of mosquitoes and should be considered. This he concluded after a study in Dar-es-Salaam (Tanzania) where water is stored in very little containers which are frequently filled and as such the mosquito population is mainly feral.

Types of water receptacles in the villages under study are comparable to those in other parts of the world where water is stored. Most of these containers are rather large and often kept outdoors. Those that were kept inside were mainly made of clay i.e. earthenware pots, very small and were inaccessible most of the time as most rooms were locked in the mornings when the inhabitants went to their farms. However, the few that were inspected were covered and less

than 1 per cent were infested. The highest percentage of infestation occurred in the metal drums (85%) followed by the earthenware pots (7%) the plastic containers (5%) and the cement containers (3%). This is noteworthy because although the cement containers are large, immovable and provide a large surface area and often have a lot of debris as they are not covered, the lowest frequency of breeding was recorded there. This is apparently due to the fact that most of them provide a suitable habitat for the predators of Ae. aegypti especially the Odonata larvae (and occasionally C. tigripes) which are longer lived and their adults prefer <sup>large</sup> expanses and more stable bodies of water to oviposit in. Thus it is not that the cement containers are not favourable oviposition places for Ae. aegypti but rather the larvae are devoured almost immediately they hatch from the egg.

Population indices calculated from the survey varied greatly within the month and between the different months of the year, and it is doubtful whether a replicate survey will give <sup>exactly</sup> the same results. Chan et.al. (1971) showed that in replicate surveys in certain portions of the city there was no difference in the premise index and in the larval density index in those particular areas of Singapore. It was only in a latter survey that they realised that the periods

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selected for the replicate surveys coincided with peaks in the annual population cycle of the species. As many indices as possible were therefore calculated to give an insight into Ae. aegypti breeding in these areas and to point out any seasonality. The single larva method (Sheppard 1966) was chosen to calculate these indices for the following reasons: It is very simple, more houses can be sampled in a short period and a less bias of occurrence of each container breeding species is obtained and gives a good insight to population dynamics in an area. The disadvantages however include that the observer must be able to identify Ae. aegypti immediately and very little information is gathered on other species breeding with the vector or the actual population density of the vector itself. To overcome these problems one whole month (September 1980) was used to practice identifying Ae. aegypti in both towns.

Tinker (1967) found out in his survey that although all the indices gave similar population values the house index was the most reliable as it varied less and changed rapidly with changing infestation at low levels.

This is important as the best index should give a clear representation of what is actually present in the environment and should be reproducible.

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Of course due to a multiplicity of environmental factors present in the field complete reproducibility is not possible. Similarly the house indices varied with climatic factors in this survey and it is however shown that there were more variations between weekly samples at Danfa than at Amasaman.

This is also evident in a few of the other indices for example, the container index varied a lot in both villages. The most consistent within a month were the Breteau and the Infested receptacle index and the larval density for both villages. Mouchet's (1971) survey in the Eastern region was at Asikasu and Akwatia which are not really near enough but there he recorded density figures of 3 and 4. Agadzi's (1982) report on the Eastern region was at Maase where a higher index of 6 was recorded. But in other parts of Ghana especially the Northern Region Mouchet (1971) recorded a density figure of about 9 with a Breteau index of 203 at Kusasi. Chinery's (1969) results however, are the most comparable but since he did not restrict himself to houses he only calculated the container index and the infested receptacle index for parts of Accra. Chinery (1969) did not refer to his values with the W.H.O. population terms but called them "percentage of positive records"

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(equivalent to container index) and "percentage infestation rate (equivalent to infested receptacle index). Values he obtained for <sup>the</sup> container index for September 1964- August 1965 was 36.7% and from September 1965 to September 1966, 46.31%. For <sup>the</sup> infested receptacle index he recorded for September 1964 - February 1965 0.07, March 1965 - August 1965, 0.68 and September 1965 - February 1966 0.31, March 1966 - August 1966, 0.31.

#### 4.8.2 Seasonality

In considering this factor it seems appropriate to discuss differences in percentages of water filled containers all year round. This might either reflect or account for differences in the breeding population. It appears that throughout the year at Danfa a high percentage of pots are filled (i.e. considering a week's sampling); normally over 80% of all the pots are full of water at Danfa and between 70 -80% at Amasaman. This reflects on the fact that the reservoir at Amasaman is nearer the houses and there are people in the village whose job is to go around selling buckets of water.. It was thus not necessary to fill all pots at a time.

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There was no obvious difference between the percentage of pots filled in the rainy season and the percentage filled in the dry season. It is noticed however, that the lowest percentage recorded for both towns was in October with a low value of 58% at Danfa and 68% at Amasaman; and the highest values, that is over 90% occurred in February, March, July and November for both villages. Although these are not the driest months of the year they all fall under the drier months of the year. The highest number of water receptacles per house were recorded in June, August and October. At Amasaman as many as 16 water containers were found in one house whereas the highest number for a single house in Danfa was 10.

As stated before, Ae. aegypti was found breeding all year round with the lowest incidence occurring in August at Amasaman where only one house was infested and in the same month there was an invasion of C. duttoni in both villages. The infested receptacles indices show that although there is no direct parallelism between its value and that of rainfall there is a close relationship especially at Danfa with peaks coinciding with high amounts of rainfall and low value during the drier months. At Amasaman however the two graphs are out of phase with the rainfall showing one peak and the

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infested receptacle index two peaks. This observation is also reflected in the container indices and rainfall graph. This can probably be explained by the fact that the habits of the inhabitants hinder the natural population fluctuation, as such there is no definite seasonal pattern. Population densities for Amasaman remained low all year round whilst at Danfa high populations were observed in March, May and July.

Ho et.al (1971) state that the influence of rainfall on Ae. aegypti populations in Singapore is not unexpected since outdoor breeding is common in the city and Rao et.al (1973) found in his survey in Tanzania that the container index closely followed and paralleled the fluctuations in rainfall.

Agadzi (1982) concluded after his survey that no definite seasonal pattern of Aedes aegypti breeding appeared and that whilst in the southern parts of Ghana there were several peaks occurring in the rainy season or soon after it, in the Northern parts peaks occurred in the dry seasons. This seems to be the situation in the present study too where peaks occurred in either the dry season i.e. February and in the wet season (May) at Amasaman and only in the wet season at Danfa (with the exception of June which had low numbers).

Chinery's (1969) survey showed that Ae. aegypti infestation was highest from May to August peaking in June and he felt that it coincided well with rainfall values observed.

It is difficult to tell whether the other species that were encountered showed any seasonality as no numbers were actually recorded, but there were exceptionally large numbers of Culex duttoni in July for both villages and very low numbers in November.

#### 4.8.3 Habits of the People

Chan et.al (1971) divided the houses that they sampled in Singapore into either Slum houses or Shop houses because although they both had water containers they were used in different ways and as such showed significant difference in the W.H.O. indices. This shows that the inhabitants greatly affect results. In this present study although there were no different types of houses, during certain survey dates especially in the rainy season, June, July, October, there were occasions when all pots had been emptied and cleaned out as people were expecting rain. If there was no rain the pots were left empty especially if the clouds still looked grey. This is what happened in June giving particularly low values for all the calculated indices.

The distance of the reservoirs also affected values and the rate of water utilization. On the average more pots were covered in Amasaman than at Danfa, this being a reflection of a higher level of education at the former village.

Service (1974) points out that the greatest mortality occurred with the constant removal of water for household purposes. This is true to a large extent but there are several pots in each compound which are left for 'emergency' purposes and many of these harbour large populations of the vector. Numbers of Ae. aegypti are controlled mainly by the continual use of water and cleaning out of the pots.

We can conclude that the chances of yellow fever breaking out in the southern portion of Ghana in the Greater Accra Region is low if conditions existing there continue to prevail. People should be educated to cover pots and other water receptacles, not to keep stagnant water and to generally keep their surroundings clean. Values obtained for the W.H.O. population indices are not very high and show that the actual mosquito density is still appreciably low. Service (1974) in his study on the Jos Plateau (Nigeria) recorded extremely high indices; this will only prove a source of danger when a virus source is allowed to enter the area.

The infested receptacle index appears to be the most reliable index giving a clear indication of events on the field. The house index and Breteau index change abruptly and constantly but that is partly because of the changing habits of the people. To a large extent mosquito density is related to amount of rainfall although there is no direct parallelism or time lag and no precise pattern or seasonality can be shown but there appears to be higher densities of Ae. aegypti in the wet months of the year. Control of numbers of Ae. aegypti population is therefore brought about by the efforts of the women and by the presence of predators and not by overcrowding or starvation.

## CHAPTER FIVE

5.0 MORPHOLOGICAL VARIATIONS OCCURRING IN  
AEDES AEGYPTI (ABDOMINAL TERGITES)  
IN SURVEY AREAS5.1 Introduction

Probably due to the adults having such a distinctive black and white colour, variations in the colour and pattern of scales on the abdomen and hind tarsus of Ae. aegypti are easily observed. These characters have been subjected to much examination to determine the genetical basis of these variations and the geographical distribution of the different taxonomic forms.

Up to date three main taxonomic forms of Ae. aegypti have been recognised based on the abdominal tergites. According to Mattingly (1957) these forms are Ae. aegypti (L) s.str., Ae. aegypti ssp. formosus Walker and Ae. aegypti var. queenslandensis Theo. (see Chap. 1.3). Ae. aegypti (L) s.str., the type form or intermediate is brownish in colour although variable in depth of colour and the others Ae. aegypti ssp. formosus Walker, is an entirely black form readily distinguishable from all other dark forms found in other parts of the world and the third type Ae. aegypti var. queenslandensis, has a pale colouration of extensive pale scales.

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The darkest form ssp. formosus normally has tergites with entirely black scales except for the basal bands and lateral spots. McClelland (1960) states that these bands are either found on tergites (2-6) for females or 3-5 for males. The lateral spots may be either of silvery concave cells which are reflective or just a matt white colour.

Specimens that are termed var. queenslandensis according to Mattingly (1957) and McClelland (1960) range in a graded series of increasing numbers of pale scales. This graded series include a few that can be termed the type form and this grading is characterized by a progressive increase in the pale scales of the first tergite and by development of pale apical bands on all the tergites. This brindled or speckled appearance is followed by an extension of both the apical and basal bands which unite in mid line to form an "hour glass" pattern.

These different forms also exhibit slightly different behaviours and this was observed by earlier workers e.g. Hill (1921) in Australia and van Someren et.al. (1955, 1958) who noticed that the pale forms were more domesticated than the darker ones. McClelland (1971) distinguishes them into feral and domestic populations.

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Mattingly and Knight (1956) suggest and it has now been accepted by other workers that the dark form was the original species and that the type form is a later development largely hybrid in character. These subspecies are also known to be able to exist in particular geographical regions and it has been shown that Ae. aegypti ssp. formosus occurs extensively and exclusively only in sub-Saharan Africa, Mattingly [1957].

The distribution of var. queenslandensis is less easy to specify but it is thought to occur in most parts of the world where this vector has been reported; it however occurs in sub-Saharan Africa "in coastal areas and one or two areas of limited inland penetration", (McClelland 1971). <sup>Summers-</sup> Connal (1927) who worked in Lagos reports both types and according to her description ssp. formosus occurred in larger percentages. It would be of interest to determine which morphological forms exist in the coastal parts of the present study area and to find out to what extent the pale form exists in such an area which is supposed to have ssp. formosus breeding predominantly.

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## 5.2 Materials and Methods

All adults that were observed were collected as larvae over a three-month period and reared in the laboratory. Initially an attempt was made at catching adults at human bait but it was time consuming and such low numbers were collected that the method was abandoned.

Jars containing the larvae being reared for these observations were well labelled showing where the larvae were caught and in what type of habitat. Most of the collections were made from peridomestic containers at Amasaman and Danfa and from various tree-holes and containers on campus. The larvae were reared in large groups and fed on Cerelac, (a baby cereal food).

Adults were examined soon after they emerged so that no scales would be lost. To avoid direct contact most were anaesthetized with ether. The abdomens were quickly inspected and the knocked out adults were either placed in the rearing cages or discarded. Those that survived were fed on 10% sucrose and offered blood as well. No genetical crosses were made.

### 5.2.1 Grading Scheme

McClelland (1960, 1971) employed a system of classification ~~involving arbitrary~~ grades of patterns of abdominal

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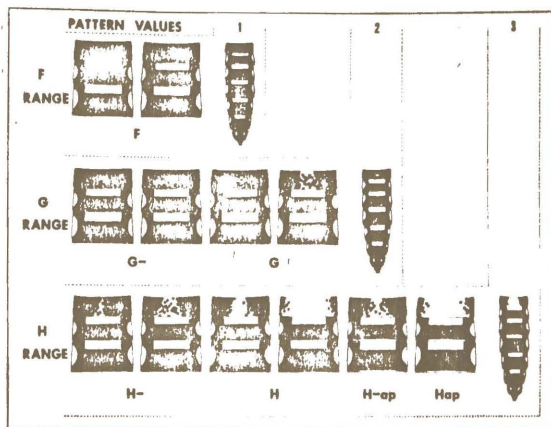


Fig. 18 Arbitrary pattern grades and pattern values corresponding to subspecies formosus and the type form of A. aegypti. (McClelland, 1971)

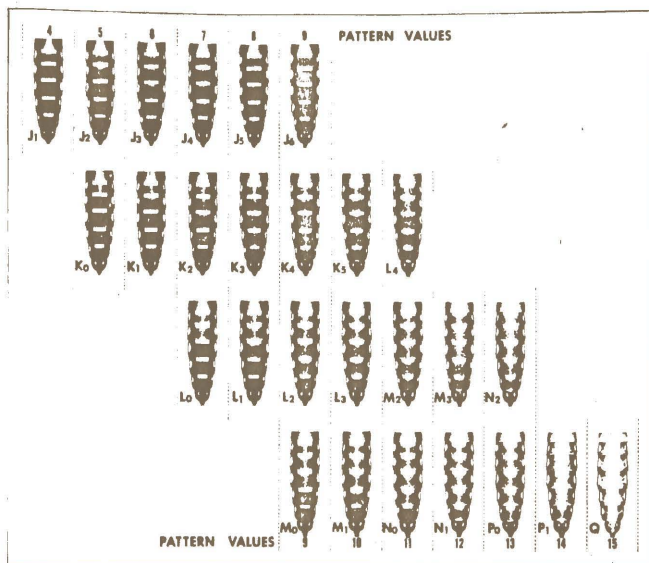


Fig. 10. Arbitrary pattern grades and pattern values corresponding to var. queenslandensis of A. aegypti. (McClelland 1971)

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tergites. This shows ranges from a grade which satisfies the definition of ssp. formosus known as grade F with no pale scales except the basal bands and lateral spots, and this grades down to another pattern having tergites with an unbroken median stripe of pale scales on all tergites grade Q for var. queenslandensis.

In between these, there are alphabets graded with digits to indicate the number of tergites (except the first) that are speckled or brindled with pale scales.

The pattern grades that correspond to sub-species formosus range from F through G to H. Letters for Ae. aegypti var. queenslandensis are J<sub>1-6</sub>, K<sub>1-5</sub>, L<sub>0-4</sub>, M<sub>0-3</sub>, N<sub>0-2</sub>, P<sub>0-1</sub>, and Q (see Figs. 18+19). J<sub>1</sub> for example will have the first segment having a narrow median section and J<sub>6</sub> an almost white first segment, see Fig. 19.

This was the criteria used in grading adult mosquitoes in this study.

### 5.3 RESULTS

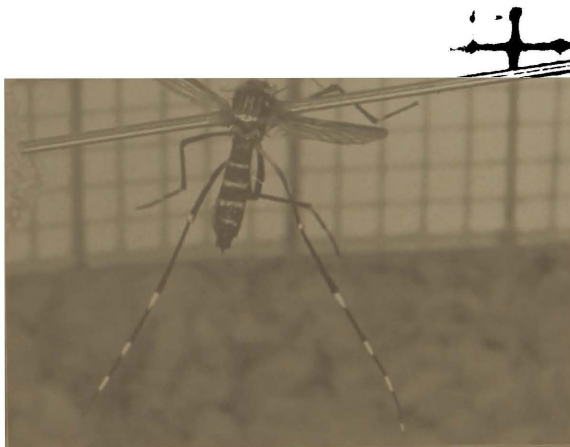
Results obtained are summarised in Table 32. From the results it appears that in all three areas Ae. aegypti ssp. formosus occurred in greater numbers than var. queenslandensis. At Amasaman the dark form accounted for about 94% of the observations, at Tema 97% and at Legon 84%. There were more

Table 32

Morphological variations in *Aedes aegypti* abdominal tergites in the 3 study areas

| Area   | Type Form                   | Abdominal Pattern Grade             | No. Collected | Percentage |
|--|-----------------------------|-------------------------------------|---------------|------------|
| Asamankese                                     | <u>ssp. formosus</u>        | F                                   | 236           | 44.60      |
|  | "                           | F (no basal bands)                  | 108           | 20.45      |
|  | "                           | G                                   | 72            | 13.63      |
|  | "                           | H <sup>-</sup>                      | 84            | 15.91      |
|  | var. <u>queenslandensis</u> | K <sub>0</sub>                      | 9             | 1.71       |
|  | "                           | K <sub>2</sub>                      | 15            | 2.84       |
|  | "                           | L <sub>0</sub>                      | 4             | 0.75       |
|  |                             | Total                               | 528           |            |
| Dunfa  | <u>ssp. formosus</u>        | F                                   | 230           | 61.63      |
|  | "                           | F (no basal bands)                  | 35            | 9.33       |
|  | "                           | F (no basal bands or lateral spots) | 16            | 4.16       |
|  | "                           | G                                   | 62            | 16.53      |
|  | "                           | H                                   | 12            | 3.21       |
|  | var. <u>queenslandensis</u> | K <sub>0</sub>                      | 20            | 5.33       |
|  |                             |                                     | Total         | 375        |
| Legon (tree-holes and tin cans)<br>(Clay pots) | <u>ssp. formosus</u>        | F                                   | 365           | 71.01      |
|  | "                           | F (no basal bands)                  | 18            | 3.50       |
|  | "                           | G                                   | 10            | 1.94       |
|  | "                           | G                                   | 10            | 1.94       |
|  | "                           | H <sub>p</sub>                      | 32            | 6.22       |
|  | var. <u>queenslandensis</u> | P <sub>0</sub>                      | 42            | 8.17       |
|  | "                           | J <sub>1</sub>                      | 30            | 5.83       |

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Longitudinal patterns of Aedes aegypti spp formosus.

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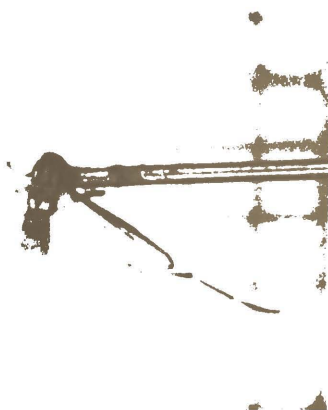


Plate 10. An entirely dark specimen of Ae. aegypti which probably can be classified under sub species formosus. This specimen however does not have any lateral and basal bands or lateral spots, on the abdomen but has the characteristic lyre shaped markings on the thorax. The abdomen is entirely black and shrivels up when etherized.

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types of var. queenslandensis at Amasaman than at Danfa. With the variety spp. formosus all three grading systems were recorded and in all areas spp formosus with no apical or basal bands were observed. (see Plates 9 & 10).

The typical grade F had white bands but most of these bands were apical and not basal. At Danfa a third type of Grade F was recorded and these had neither apical bands nor lateral spots and the general appearance was of a purplish black colour. These were seen to shrivel up when etherized whilst all other specimens retained their shape. Observations show that a wider range of the known Ae. aegypti abdominal grade patterns were collected at Legon than at Amasaman or Danfa.

#### 5.4 DISCUSSION

The population of Ae. aegypti in these survey areas <sup>appears</sup> to be largely of the variation ssp. formosus or the dark type and this is in accordance with previous observations by earlier workers, <sup>Summers-</sup>Connal 1927; McClelland 1971, as this area is part of sub-Saharan Africa. Results obtained indicate higher percentages of the dark type in all the study areas. However being coastal areas it is of no wonder that several grades of the sub-species var. queenslandensis were reported.

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This black form has been recognised as being the only one of the three different types capable of forming fully wild populations but whilst the pale form bred true, the dark type could segregate to both pale and dark forms (Hill 1927). It is known, however, to become easily domesticated under conditions of urbanization. At Amasaman, which has been described as a busy town, both ssp. formosus and var. queenslandensis were reported and the latter had a larger variety of grades than at Danfa, although the overall percentage of var. queenslandensis for the 2 towns is comparable (5.3%), and this is probably due to urbanization and transportation to and from the capital which is coastal.

Danfa on the other hand is a rural village and there is not much communication with the capital; therefore the mosquito population is mainly domestic having peridomestic habitats, yet the dark form which is supposed to be the wild type occurs in larger numbers. This population may most probably be a part of the feral population in the surrounding forests as Danfa is surrounded by forests and farms. The situation at Legon is rather interesting because although there is extensive urbanization there are records of both the pale and dark forms and the type form.

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The dark forms were collected almost entirely from the tree-holes and a few tin cans whilst the var. queenslandensis occurred in the earthenware pots placed around. The pale forms were never recorded from the tree-holes.

Mattingly (1957) reported that the type form is either domestic or semi-wild, that var. queenslandensis is exclusively domestic and that ssp. formosus normally has an almost 100% preference for natural breeding places but then in urban conditions the percentage may be as low as 10% in these natural breeding places. In rural areas where there are domestic pots only 50% may be found breeding in natural breeding sites. The Legon population therefore consists of a feral population existing in feral habitats and a domestic population comprising of both ssp. formosus and var. queenslandensis breeding in available water receptacles i.e. domestic and peridomestic habitats. It may very well be the spill-over of the feral population that is acting as a domestic type in the earthenware containers as they were the available habitats.

Mattingly (1957) states that the ssp. formosus rarely or never bites man but prefers animals whilst the var. queenslandensis behaves in exactly the opposite manner.

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The few adults (4%) caught at human bait showed about a 70% percentage of dark (70%) and pale forms (30%) attempting to bite.

Variations in taxonomy were not too difficult to see in the mosquitoes caught except for grades  $J_1$  and  $H_{ap}$  which appear very similar. Although McClelland's (1971) grading system does not include dark specimens with no basal bands, or no basal band and no lateral spots, since those that were encountered were totally black, they were placed under the grade F. A picture of one specimen he had, showed an example of the abdomen of a dark female without basal bands which he also graded as F.

Summers-Connal (1927) in Lagos also observed many varieties which eventually classify under McClelland's (1971) scheme as the two main types. She had large percentages of sub-species formosus but with those she observed, most had typical basal bands and those that had apical bands only formed the smaller percentage. The population found here seems to be those that have mainly apical bands and that appears to be the rule rather than the exception. Both apical and basal bands in a segment that she described seem to be the var. queenslandensis

214.

with grades of either  $L_{0-3}$ ,  $M_{0-3}$ ,  $N_{0-2}$ , ..... Q. Those also appeared in smaller percentages but were significant enough. Such grades were not too common in this survey as well.

The type form were observed on three occasions but it was not possible to grade them as they got destroyed. They are however very conspicuous due to their overall brown colour and were collected from earthenware pots on the University campus.

The palest type collected were grade  $P_0$  from two separate collections in the pots at Legon. They had extensive white scales running down their backs for at least 6 segments but the background scales were very dark.

With the ssp. formosus the variations occurred with the entirely dark forms that had neither lateral spots near basal bands. They were abundant at Danfa. The specimens collected from the villages had matt white lateral spots whilst those found in the tree-holes had silvery reflective white scales as the spots.

Other collections graded from parts of Ghana were samples sent to McClelland (1971) by Drs. Coker and Graig in 1961. These were egg batches collected from peridomestic

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habitats mainly and the varieties of adults were ssp. formosus with grades G, H<sub>ap</sub> and J<sub>1</sub>. These collections were all from the Volta Region (Salakope and Sokode Etoe) and as these are not coastal towns, there might not be a large percentage of var. queenslandensis there at all.

The basis for all these variations has been shown to be genetic and the pale form has been observed to breed true and maintain the characters portrayed for at least some generations (Summers Connal 1927). Shidrawi (1955) believes that there is a tendency towards maternal inheritance. Mattingly (1957) based all these differences on certain dominant genes that yielded paleness especially in the dark forms and maintained them in the pale forms. McClelland (1971) feels too much fuss has been made about genetic and geographical discontinuity which do not really exist so rigidly and as such these forms should be recognised first as polymorphs rather than polytypes.

Conclusions that can be drawn are that the variety ssp. formosus is more abundant in the present study area than the var. queenslandensis and it is believed that the darker forms do form the wild population which is segregating into paler forms which then adapt more to a domestic

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way of life. But to a large extent the possible polymorphs found will depend on the type of habitats available i.e. where there are domestic, peridomestic or feral habitats they will subsequently promote their domestic or feral populations. However in areas where the dark form is virtually non-existent (for example Southern India, Rao et.al. 1970) the type form and var. queenslandensis have been reported breeding in tree-holes.

CHAPTER SIX

6.0 CONCLUSIONS AND SUMMARIES

6.1 Conclusions

Aedes aegypti has long been recognised as the vector of yellow fever and has been studied more than any other mosquito. Although so much information exists on its biology, ecology, physiology, genetics and its eradication Ae. aegypti continues to successfully exist as domestic and peridomestic populations breeding in peridomestic water receptacles and also as a feral population in feral habitats and subsequently major epidemic of yellow fever still keep occurring. This study has shown that total eradication of Ae. aegypti is bound to be very difficult because of certain characteristics that this vector possess.

The eggs of Ae. aegypti have been shown to be resistant to adverse environmental conditions and in favourable atmospheric conditions are capable of remaining in a state of diapause for at least 1 year. These eggs are very small and are laid in large numbers and require just a little amount of water and a hatching stimulus to initiate hatching. Larvae and pupae can also withstand high temperatures.

Populations in village receptacles are regulated mainly by ~~the~~ the food and to some extent over crowding

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as shown in this study and by Subra (1977). Subra (1982) also confirms the finding that human behaviour is a very important factor as the women keep on emptying highly infested pots of water thus affecting populations. Service (1983) however feels that although such factors regulate populations in village pots this factor cannot be the answer to all other situations e.g. feral populations.

Predation also is effective in population reduction but as seen in these studies Ae. aegypti avoids excessive predation by breeding in different habitats from the most effective predator (Tox. brevipalpis) Service (1983) feels that predators are not the key factors for controlling population size. It is recommended that more intense studies should be carried out into all possible predators especially Odonata nymphs taking account of preferred breeding sites. Thus specific predators could be used in biological control programmes taking account of the various possible habitats in the area.

Tree-holes are significant breeding sites and their contribution to adult Ae. aegypti populations varies seasonally. Ae. aegypti and other closely related species have shown significant seasonality and this factor should

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be considered carefully in each control programme. The size and location and the type of debris in it affects the numbers of Ae. aegypti to a large extent and it is advisable that all tree-holes are blocked to reduce feral populations.

Human behaviour is a very important feature in all control programmes as Ae. aegypti is greatly adapted to human environment. So mass education programmes should be conducted periodically to point out the dangers of disease transmission and simple methods of mosquito control e.g. the use of kerosene and the proper disposal of all litter especially discarded tins.

Proper use (below pollution proportions) of Abate could be encouraged in the villages as it has no offensive odour or taste and is not toxic to man. Because until proper pipe borne water is established every where the presence of Ae. aegypti will still prevail. As pointed out by W.H.O., a density figure index of 5 indicates that the population size of Ae. aegypti has reached a level which presents a threat of the transmission of yellow fever once a source of virus enters the area.

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An insight to the population dynamics of Aedes aegypti observed from life budget studies and the calculated W.H.O. indices shows that Legon and surrounding areas are not prominent Ae. aegypti foci areas. This situation is not permanent and can easily change and all efforts should be made to maintain the existing populations or eradicate the vector completely.

## 6.2 Summary

1. The ecology of the eggs, larvae, pupae and adults of Aedes aegypti were studied at Legon, Amasaman and Danfa. Studies were aimed at obtaining additional information on how Ae. aegypti are able to survive and maintain such large populations in these study areas. And thus be able to plan future control programmes to eradicate it entirely in future. The last major yellow fever epidemic occurred in 1979/80 claiming 120 lives out of 494 cases reported.

2. Eggs of Ae. aegypti are laid in large batches (mean  $68.6 \pm 248$ ) which are capable of withstanding adverse conditions of moisture if sufficiently conditioned. Atmospheric humidities of 60% and above are favourable for 1 year diapause whilst a large percentage (50%) of the eggs die if exposed to humidities below 40%.

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3. Larvae are killed after short exposure (3min) to high temperatures of 48°C. Pupae can however stand a short exposure (2mins) to 50°C.
4. Population regulation in larvae breeding in pots may be brought about by starvation or a reduction of available food in high density breeding containers. Overcrowding of larvae has the effect of prolonging pre-imaginal durations and there is also an increase in mortalities.
5. Predation of Ae. aegypti by Tox. brevipalpis, Culex tigripes and Brachythermis leucostica showed that Tox. brevipalpis was more efficient than C. tigripes and more advantageous as it lived longer. The Odonata nymphs are also effective but since they are facultative feeders its assumed that in the field their overall efficiency will be less than Tox. brevipalpis. Tox. brevipalpis and C. tigripes prefer Aedes aegypti to certain common Culex species.
6. Significant predation is avoided by Ae. aegypti as it breeds mainly in domestic receptacles and Tox. brevipalpis in feral habitats.
7. Key mortality factors analysis of different population densities in the laboratory of Ae. aegypti shows that at

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high densities (150-270 larvae per 100ml of water) factor  $K_4$  which acts between instar 4 and pupae is clearly density dependant. Greater mortalities will occur as the population size increases.

8. Life budgets of an Ae. aegypti population breeding in the laboratory is greatly affected by the amount of food present. Excess food caused high mortality ( $K_T = 0.75$ ) and insufficient food the least mortality ( $K_T = 0.11$ ).

9. The longevity of Ae. aegypti population breeding in tree-holes is effected by the population density. In comparison with laboratory populations the duration of the 7<sup>rd</sup> instars (a population of mean density 365.85) in the tree-hole was prolonged (4.1 days) whereas the 3<sup>rd</sup> instars in the laboratory lasted 2.5 days. Total duration in the tree-hole was 13.53 days and in the laboratory 9.72 days.

10. Life tables constructed for the population breeding in the tree-holes shows a higher survival expectation in the earlier instars than in the latter ones. Key mortality factor here was  $K_4$ .

11. An analysis of Ae. aegypti breeding in tree-holes in March-May 1982 shows that only 30% of the initial population emerge as adults. Mortalities are attributed to

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overcrowding and the presence of toxic substances from the stagnant water and the larvae themselves. An earlier study in June-August 1981, was abandoned due to excessive mortality due to the presence of Tox. brevipalpis.

12. Twelve species of mosquitoes including Ae. aegypti were recorded breeding in various tree-holes on the University campus. They are Ae. aegypti, Ae. luteocephalus, Ae. stokesi, Ae. unilineatus, Ae. simpsoni, Ae. apicoargenteus, Ae. dendrophilus, Ae. vittatus, C. decens, C. horridus, C. pruina, Tox. brevipalpis. Ae. aegypti formed 63% of population breeding in all tree-holes, 51% of tin can populations and 53% of these breeding in clay pots.

13. In this study Ae. dendrophilus was found breeding only in tree-holes. Ae. unilineatus specifically in tin cans and C. tigripes and C. duttoni exclusively in clay pots. The other species could be found in varying percentages in any of the three habitats.

14. Eggs found attached to dry debris collected from the tree-holes in the dry season yielded only three species, Ae. aegypti, Ae. luteocephalus, Ae. stokesi.

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15. It was not established as to whether tree species played an important role in habitat selection. But it is seen that the size of the hole was directly related to the number of inhabitants.

16. With the ovitraps, height was a major determinant to the numbers of mosquito species inhabitants. It appears that mosquitoes prefer habitats of height of 3/4m - 2m for breeding.

17. Marked seasonality is observed with mosquito species throughout the year. Tox. brevipalpis for example abandons tree-holes in the dry season for the tin cans.

18. W.H.O. indices (House, Containers, Breteau, Infested receptacles and larval density) were calculated over a 15 month period by conducting surveys of mosquitoes in water receptacles in Danfa and Amasaman.

19. Danfa supports a larger population of Ae. aegypti and calculated density figures of above 5 were recorded very often showing a population with a higher potential for the transmission of yellow fever than the population at Amasaman.

20. The Breteau and Infested receptacles and larval density for both villages were the most reliable indices. They give an exact representation of what actually happens to the populations in the villages.

21. A close relationship exists between the annual rainfall values and infested receptacle indices at Danfa. At Amasaman the two parameters were out of phase and it is believed that the indices values are greatly affected by the habits of the inhabitants.

22. Populations are regulated by the presence of a few predators and by women folks emptying and filling pots regularly especially whenever infestations are high.

23. Morphological variations occurred in the abdominal tergites of Ae. aegypti breeding in both feral and peridomestic habitats. All three varieties, Ae. aegypti ssp. formosus, Ae. aegypti s.str., Ae. aegypti var queenslandensis existed in the study areas.

24. In each area Ae. aegypti ssp. formosus formed about 70% of all catches. The Ae. aegypti var queenslandensis range that were recorded were  $K_0$ ,  $K_2$ ,  $L_0$ ,  $J_1$ , and the brown type form Ae. aegypti s.str.

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25. In Legon the feral populations breeding in the tree-holes were only of the sub-species formosus and the type form was found breeding only in the clay pots.

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\*Originals not seen.

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APPENDIX 1

Yellow fever cases and deaths reported over a 10 year period in Ghana\*

|    | Jan. |    | Feb. |   | Mar. |   | Apr. |    | May |    | June |    | July |   | Aug. |    | Sept. |   | Oct. |    | Nov. |   | Dec. |    | Total |     |   |   |
|----|------|----|------|---|------|---|------|----|-----|----|------|----|------|---|------|----|-------|---|------|----|------|---|------|----|-------|-----|---|---|
|    | d    | c  | d    | c | d    | c | d    | c  | d   | c  | d    | c  | d    | c | d    | c  | d     | c | d    | c  | d    | c | d    | c  | d     | c   | d |   |
|    | -    | -  | -    | - | -    | - | -    | -  | -   | -  | -    | -  | -    | - | -    | -  | -     | - | -    | -  | -    | - | -    | -  | -     | -   | - | - |
|    |      |    |      |   |      |   |      |    |     | 1, | 1    |    |      |   |      | 3, | 3     |   |      |    |      |   |      |    |       | 4,  | 4 |   |
| 7  |      |    |      |   |      |   |      |    |     |    |      |    | 1,   | 1 | 1,   | 1  |       |   | 3,   | 3  |      |   |      |    |       | 5,  | 5 |   |
| 7  |      |    |      |   |      |   |      |    |     |    |      |    |      |   |      |    |       |   |      |    |      |   |      |    |       |     |   |   |
| 7a |      |    |      |   |      |   |      |    |     |    |      |    | 1,   | 0 |      |    |       |   |      |    |      |   |      |    |       | 1,  | 0 |   |
| 7b |      |    |      |   |      |   |      |    |     |    |      |    |      |   |      |    |       |   |      |    |      |   |      |    |       |     |   |   |
| 7c |      | 1, | 1    |   |      |   |      |    |     |    |      |    |      |   | 15,  | 2  | 14,   | 4 | 44,  | 19 | 26,  | 6 | 9,   | 0  | 109,  | 32  |   |   |
| 7d |      | 3, | 12,  | 0 | 5,   | 1 | 6,   | 2  | 14, | 6  | 7,   | 3  |      |   | 2,   | 0  | 11,   | 2 | 14,  | 2  | 44,  | 6 | 88,  | 15 | 219,  | 45  |   |   |
| 7e | 12,  | 19 | 49,  | 9 | 33,  | 6 | 61,  | 10 | 53, | 10 | 49,  | 19 | 34,  | 9 | 30,  | 16 | 27,   | 3 | 22,  | 6  | 14,  | 4 | 10,  | 9  | 424,  | 120 |   |   |

\*(Min. of Health Epid. 10yr. Report).

c = cases  
d = deaths

## APPENDIX 2

Data from International Critics table 3, 373  
 showing relationship between concentration -  
and Vapour Pressure over KOH Solution

At 20°C

| Conc. of Solution                      |   | Water Pressure over Solution in mm<br>and equilibrium R.H. |        |
|--|---|--|--------|
| g KOH per<br>100g water in<br>Solution | Wt. % of<br>Solution...<br>KOH per 100g<br>Solution | V.P.   | R.H. % |
| 0                                      | 0   | 17.54  | 100    |
| 5                                      | 4.76  | 17.00  | 96.93  |
| 10                                     | 9.09  | 16.30  | 92.94  |
| 20                                     | 16.67   | 14.7   | 83.81  |
| 30                                     | 25.08   | 12.9   | 73.55  |
| 40                                     | 28.57   | 10.9   | 62.15  |
| 50                                     | 33.33   | 8.9  | 50.75  |
| 60                                     | 37.50   | 7.2  | 41.05  |
| 80                                     | 44.44   | 4.4  | 25.09  |
| 100                                    | 50.00   | 2.6  | 14.82  |

## APPENDIX 3

Species preference of 3 predators

| Predator                                      | No. of prey given to eat<br>(instar in brackets) |                    | No. of prey eaten  |                    |
|---|--|--------------------|--------------------|--------------------|
|   | <u>Aedes aegypti</u>                             | <u>Culex sp.</u>   | <u>Ae. aegypti</u> | <u>Culex sp.</u>   |
| Odonata nymph<br>(3rd instar)                 |  | <u>C. horridus</u> |                    | <u>C. horridus</u> |
|   | 10 (3)   | 10 (3)             | 10                 | 10                 |
|   | 15 (3)   | 5 (3,4)            | 15                 | 4                  |
|   | 5 (3)  | 15 (3,4)           | 5                  | 13                 |
| <u>Tox. brevipal-<br/>pis</u><br>(4th instar) |  | <u>C. horridus</u> |                    | <u>C. horridus</u> |
|   | 10 (4)   | 10 (3)             | 10                 | 7                  |
|   |  | <u>C. decens</u>   |                    | <u>C. decens</u>   |
|   | 10 (4)   | 10 (4)             | 9                  | 5                  |
|   | 5 (4)  | 10 (4)             | 5                  | 6                  |
| <u>Culex tigripes</u>                         |  | <u>C. decens</u>   |                    | <u>C. decens</u>   |
|   | 10 (4)   | 10 (4)             | 10                 | 10                 |
|   |  | <u>C. horridus</u> |                    | <u>C. horridus</u> |
|   | 10 (3)   | 9 (4)              | 10                 | 9                  |

## APPENDIX 3a.

Calculated values of Attack coefficient ('a') and handling time ('Th').

| Predator size       | Prey size | Attack coefficient | Handling time | Correlation | B.     |
|---------------------|-----------|--------------------|---------------|-------------|--------|
| 1st and 2nd instars | 1         | -0.0672            | -0.0582       | 0.2383      | 0.0250 |
|                     | 2         | -0.1548            | -3.7844       | 0.7145      | 0.2545 |
|                     | 3         | -0.1942            | -2.7016       | 0.9446      | 0.4183 |
|                     | 4         | -0.1315            | -1.6965       | 0.4023      | 0.3295 |
| 3rd and 4th instars | 1         | -0.0971            | -0.4065       | 0.3680      | 0.0534 |
|                     | 2         | -0.1959            | -2.1617       | 0.8379      | 0.2099 |
|                     | 3         | -0.1042            | -0.6227       | 0.2751      | 0.1220 |
|                     | 4         | -0.0998            | -1.1014       | 0.3046      | 0.1147 |

Some of the calculated values were too high and as such functional response curves

(expected numbers eaten) for some instars could not be fitted.

## APPENDIX 4

Data for a population density study carried out in a tree-hole in June/August.

| Date   | Sample | No. of larvae/Pupae |     |     |     |   | Remarks  |
|--------|--------|---------------------|-----|-----|-----|---|--|
|        |        | 1st                 | 2nd | 3rd | 4th | P   |  |
| June   | 1      | 425                 | -   | -   | -   | -   | Rained previous day. 1 4th instar and 1 Pupae of <u>Tox. brevipalpis</u> were found. |
|        | 2      | 3                   | 20  | -   | -   | -   | -  |
| July   | 3      | 180                 | 431 | -   | -   | -   | Rained night before. 3 2nd instar <u>Tox. brevipalpis</u> found in hole.             |
|        | 4      | -                   | -   | 54  | 30  | 22  |  |
|        | 5      | 127                 | 266 | -   | -   | 12  | Rained again.  |
|        | 6      | 29                  | 161 | 97  | -   | -   |  |
|        | 7      | -                   | -   | 53  | -   | -   | 5 2nd and 3rd <u>Tox. brevi.</u> in the hole   |
|        | 8      | 280                 | 20  | -   | -   | -   | Light rain in the night 3 4th instar <u>Tox. brev.</u> seen.                         |
|        | 9      | 20                  | -   | -   | -   | 1 4th instar and 1 pupa of <u>Tox. brev.</u> left |  |
| August | 10     | 34                  | 10  | -   | -   | -   | A few larvae of <u>C. decens</u> and <u>Ae. luteocephalus</u> seen.                  |
|        | 11     | 12                  | 15  | 2   | -   | -   | 2, 2 instar <u>Tox. brevipalpis</u> seen   |

First attempt at collection of data for life tables studies. The investigation was carried out at 3 day interval and was stopped because the Ae. aegypti population was not given a chance to survive in the tree-hole due to the constant presence of the predator Tox. brevipalpis. The predators were counted during counting the sample and as such ate of the larvae during day.

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## APPENDIX 5

Numbers of the different species collected on successive sampling days. Tree hole 1.

| No. of larvae | <u>Ae. aegypti</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. apicoargenteus</u> | <u>Culex decens</u> | <u>Culex pruina</u> | <u>Tox. brevipalpis</u> |
|---------------|--------------------|--------------------------|--------------------|---------------------------|---------------------|---------------------|-------------------------|
| 55            | 41                 | 10                       | -                  | -                         | -                   | -                   | -                       |
| 90            | 60                 | 21                       | -                  | -                         | 5                   | -                   | -                       |
| 40            | 32                 | -                        | 8                  | -                         | -                   | 2                   | -                       |
| 41            | 26                 | 6                        | -                  | -                         | 7                   | -                   | -                       |
| 20            | 10                 | 6                        | -                  | -                         | -                   | -                   | -                       |
| 14            | -                  | 8                        | 6                  | -                         | -                   | -                   | -                       |
| 20            | 6                  | -                        | 6                  | -                         | 3                   | -                   | 4                       |
| 18            | 15                 | -                        | -                  | -                         | 3                   | -                   | -                       |
| 24            | 10                 | -                        | 2                  | 2                         | -                   | 6                   | 4                       |
| 250           | 122                | -                        | -                  | -                         | 128                 | -                   | -                       |
| 77            | 35                 | 12                       | 8                  | -                         | 16                  | 3                   | 6                       |
| 37            | 10                 | 6                        | 5                  | -                         | 16                  | -                   | -                       |
| 40            | 21                 | 5                        | -                  | 1                         | -                   | -                   | -                       |
| 20            | 5                  | -                        | -                  | -                         | -                   | -                   | 15                      |
| 15            | -                  | 5                        | -                  | -                         | 1                   | -                   | 13                      |
| 17            | -                  | -                        | -                  | -                         | -                   | -                   | 17                      |
| 70            | 30                 | 25                       | 6                  | 3                         | -                   | 2                   | -                       |
| 12            | -                  | -                        | -                  | -                         | -                   | -                   | 12                      |
| 31            | 10                 | 15                       | 4                  | -                         | -                   | -                   | 2                       |

248.

5 Cont'd.

| No. of larvae | <u>Ae. aegypti</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. apicoargenteus</u> | <u>Culex decens</u> | <u>Culex pruina</u> | <u>Tox. brevipes</u> |
|---------------|--------------------|--------------------------|--------------------|---------------------------|---------------------|---------------------|----------------------|
| 36            | 8                  | 26                       | -                  | -                         | -                   | -                   | -                    |
| 67            | 4                  | 26                       | 11                 | 1                         | 1                   | 10                  | 2                    |
| 40            | 8                  | 18                       | 6                  | -                         | -                   | -                   | -                    |
| 48            | 22                 | 4                        | 8                  | -                         | -                   | -                   | 4                    |

APPENDIX 6

Numbers of mosquito species collected during sampling.

Tree hole 2

| No. of larvae | <u>Ae. aegypti</u> | <u>Ae. tritaeniorhynchus</u> | <u>Ae. stokesi</u> | <u>Ae. apicoargenteus</u> | <u>Culex decens</u> | <u>Tox. brevipalpis</u> | <u>Ae. simpsoni</u> |
|---------------|--------------------|------------------------------|--------------------|---------------------------|---------------------|-------------------------|---------------------|
| 20            | 15                 | 4                            | -                  | -                         | 1                   | -                       | -                   |
| 8             | 6                  | 0                            | -                  | -                         | -                   | -                       | -                   |
| 66            | 40                 | 11                           | 8                  | -                         | -                   | -                       | 6                   |
| 39            | 23                 | 15                           | -                  | -                         | -                   | -                       | -                   |
| 56            | 30                 | 10                           | -                  | -                         | -                   | -                       | -                   |
| 50            | 26                 | 20                           | -                  | -                         | -                   | -                       | -                   |
| 50            | 24                 | 10                           | 14                 | -                         | -                   | -                       | -                   |
| 23            | 16                 | -                            | -                  | 6                         | -                   | -                       | 1                   |
| 13            | 2                  | 7                            | -                  | -                         | -                   | 2                       | -                   |
| 24            | 14                 | 8                            | 2                  | -                         | -                   | -                       | -                   |
| 12            | 2                  | 4                            | 1                  | -                         | -                   | -                       | 1                   |
| 22            | 6                  | 14                           | -                  | -                         | 2                   | -                       | -                   |
| 10            | -                  | 2                            | 8                  | -                         | -                   | -                       | -                   |
| 12            | 2                  | 3                            | 6                  | -                         | -                   | -                       | -                   |
| 15            | 0                  | 7                            | 6                  | -                         | -                   | -                       | -                   |
| 22            | 9                  | 10                           | 1                  | -                         | 2                   | 2                       | -                   |
| 35            | 2                  | 8                            | 16                 | -                         | 4                   | 1                       | -                   |
| 19            | 6                  | 6                            | 7                  | -                         | -                   | -                       | -                   |

250.

APPENDIX 7

Numbers of different mosquito species collected during sampling  
Tree-hole 5

|      | No. of larvae | <u>Ae. aegypti</u> | <u>Ae. luteocephalus</u> | <u>Ae. stokesi</u> | <u>Ae. simpsoni</u> | <u>C. horridus</u> | <u>C. pruina</u> | <u>Tox. brevipalpis</u> | <u>Ae. dendrophilus</u> |
|------|---------------|--------------------|--------------------------|--------------------|---------------------|--------------------|------------------|-------------------------|-------------------------|
| ie   | 4             | 4                  | -                        | -                  | -                   | -                  | -                | -                       | -                       |
|      | 42            | 42                 | -                        | -                  | -                   | -                  | -                | -                       | -                       |
| ly   | 30            | 30                 | -                        | -                  | -                   | -                  | -                | -                       | -                       |
|      | 70            | 44                 | -                        | 27                 | -                   | -                  | -                | -                       | -                       |
| gust | 30            | 25                 | 8                        | 9                  | -                   | -                  | -                | -                       | -                       |
|      | 58            | 26                 | 8                        | 10                 | -                   | -                  | -                | -                       | -                       |
| pt.  | 50            | 21                 | 11                       | 12                 | -                   | -                  | -                | -                       | -                       |
| v.   | 45            | 5                  | 5                        | 10                 | -                   | 18                 | -                | -                       | -                       |
|      | 20            | 3                  | 22                       | 5                  | -                   | 9                  | -                | -                       | -                       |
|      | 68            | 5                  | 0                        | 5                  | -                   | 40                 | -                | -                       | -                       |
| z.   | 80            | 56                 | -                        | -                  | 12                  | -                  | -                | -                       | 10                      |
|      | 50            | 22                 | 8                        | -                  | 14                  | -                  | -                | -                       | 2                       |



## Appendix 8 Cont'd.

|      | O.T.  | <u>Ae.</u><br><u>ægypti</u> | <u>Ae.</u><br><u>simpsoni</u> | <u>Ae.</u><br><u>luteo.</u> | <u>Ae.</u><br><u>stokesi</u> | <u>Ae.</u><br><u>unili</u> | <u>C.</u><br><u>decens.</u> | <u>C.</u><br><u>pruina</u> | <u>Tox.</u><br><u>brevipalpis</u> |
|------|-------|-----------------------------|-------------------------------|-----------------------------|------------------------------|----------------------------|-----------------------------|----------------------------|-----------------------------------|
|      | O.T.1 | 10                          | -                             | 10                          | -                            | -                          | -                           | -                          | -                                 |
|      | " 2   | -                           | -                             | -                           | -                            | -                          | -                           | 4                          | 4                                 |
|      | " 3   | -                           | -                             | 16                          | 2                            | 2                          | -                           | -                          | -                                 |
|      | " 4   | 6                           | -                             | 1                           | 2                            | -                          | -                           | -                          | -                                 |
|      | " 5   | 46                          | -                             | 10                          | -                            | 20                         | -                           | -                          | -                                 |
|      | " 6   | -                           | -                             | 6                           | -                            | -                          | -                           | -                          | -                                 |
|      | " 9   | 8                           | -                             | -                           | -                            | -                          | -                           | -                          | -                                 |
| Dec. | O.T.1 | 6                           | -                             | 3                           | -                            | -                          | -                           | -                          | 1                                 |
|      | " 2   | 4                           | -                             | 5                           | -                            | -                          | -                           | -                          | -                                 |
|      | " 3   | 3                           | 16                            | -                           | -                            | -                          | -                           | -                          | 1                                 |
|      | " 4   | 11                          | -                             | -                           | -                            | -                          | -                           | -                          | -                                 |
|      | " 5   | 22                          | 3                             | 7                           | -                            | -                          | -                           | -                          | -                                 |

O.T.1 - Samanea samanO.T.4 Azadiracta indicaO.T.7 - Ficus platyphyllaO.T.2 - Delonix regiaO.T.5 Citrus sp.O.T.8 - Musa sp.O.T.3 - Mangifera indicaO.T.6 Elaeisis guineensis

O.T.9 - Grass clump

APPENDIX 9

Description of the different mosquito species collected in the study area from tree-holes and other breeding sites.

The 12 different species with emphasis on the Aedes species are briefly discussed and described below to enable an observer to identify the most common ones easily without having to look through long keys which may not always be available or easy to use. However, the morphology of most mosquito larvae is given in detail by Hopkins (1952) and that of the adults by Edwards (1941).

- 1) Aedes (Stegomyia) aegypti Linn.



Thorax

Most common species recorded during this survey and was found in all tree-hole. It is a known three-hole breeder and details of its morphology are given by Christopher (1960). In the field the larvae can be identified by their short dark siphon and almost pure white colouration although grey shades are often observed, which apparently depends on the organic material available. With the aid of a hand lens it is easy to see at the base of the meso and meta pleural tufts that there are very strongly sharply pointed spines. The adults were mostly of the subspecies formosus and are thus very black with the characteristic white lyre shaped pattern on the thorax. (See plates 1 and 2).

2) Aedes (Stegomyia) luteocephalus Newstead.

Thorax

The adult is a large dark species with characteristic golden and whitish metallic scales as seen in the diagram; it also has yellow spines on the thorax. The abdomen has yellow basal bands. The larva is usually larger than Ae. aegypti and always appears white. It has a siphonal index of about  $2\frac{1}{2}$ . It has been recorded to breed in tree-holes by many authors, Hopkins (1952).

3) Aedes (Aedimorphus) stokesi Evans. Larvae are more than either Ae. luteocephalus or Ae. aegypti and have a siphonal index of about 3; they normally appear brown. The adults are smallish and appear dark

Thorax

brown too with virtually no markings on the thorax at all except for 2 small silvery white patches on each shoulder. Very frequently found in tree-holes and can stand a high degree of pollution. They occurred frequently in most of the tree-holes examined.

4) Aedes (Stegomyia) apicoargenteus Theobald

Thorax

Adults are small and dark and have 2 round white spots on the anterior half of the thorax. The scutellum has a white middle lobe and 2 black outer lobes. The larvae are grey with a black siphon which is conical and short, and has an index of about  $1\frac{1}{2}$ . The anal segment is heavily sclerotised. It has been reported to be very common in tree-holes by Hopkins (1952) although it was not observed often in this study.

5) Aedes (Stegomyia) dendrophilus Edwards

Thorax

Larva is whitish and the thorax has large very conspicuous stellate setae. Siphon is dark and has a siphonal index of about  $2\frac{1}{2}$ . The thoracic markings of the adult could easily be confused with that of Ae. simpsoni as they both have large white spots on the anterior position. However this species has a single mid line whilst Ae. simpsoni has two. (see Gerberg and van Someren 1970).

6) Aedes (Stegomyia) simpsoni Theobald



Thorax

The larvae looks a bit like Ae. aegypti but the siphon is yellowish brown and looks rather conical and is much shorter. It is found more frequently in plant axile than in tree-holes. The adult which is dark in colour has four white spots on the thorax but the anterior ones are much larger than the posterior ones. There are also four short lines in the lower mid portion. Common in discarded pots and tins.

7) Aedes (Stegomyia) unilineatus Theobald



Thorax

The larvae of this species is yellowish brown and has plenty of stellate hairs all over the body. There is a characteristic white median stripe down the thorax of the adult. This was commonly found in the tin cans during this survey although other workers like Ingram (1919) recorded it in a rot hole in Northern Ghana.

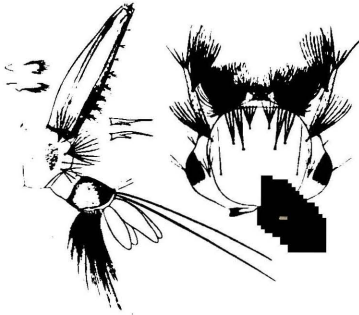
8) Aedes (Stegomyia) vittatus Bigot

Thorax

Adults are a brownish black colour and have 3 conspicuous pairs of small round white spots on the thorax. The femora is characteristic as it has narrow white pre apical rings. The larvae are grey with a blackish head. Siphonal index  $1\frac{1}{2}$  and the siphon is conical. Hopkins (1952) describes it as an atypical Stegomyia as it does not breed primarily in tree-holes or domestic utensils but rather in rock pools. In this study it was found breeding in earthenware pots.

9) Culex (Culex) duttoni Theobald.

Larvae are a pale grey brown colour, the siphon is also pale and has a characteristic broad dark band near the apex. The siphonal index is about  $4\frac{1}{2}$  and has a strong biconvex shape. Adults are a pale brown colour slightly larger than Ae. aegypti and the tarsi are distinctly ringed. Larvae are commonly found in water receptacles, ditches, and in rock ground pools.

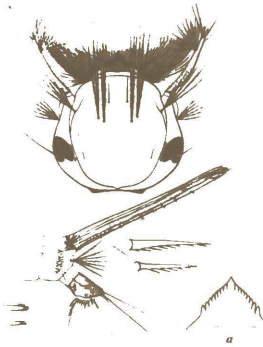
10) Culex (Culex) pruina Theobald.

The adults are easily identified because of its entire green colouration. It is a small species and looks rather delicate. The larva has a siphonal index of about 4, siphon is in barrel shape and there is a dense cover of spicules on the siphon at least on the central portion. It has not been recorded breeding in tree-holes extensively yet.

11) Culex (Culex) decens Theobald

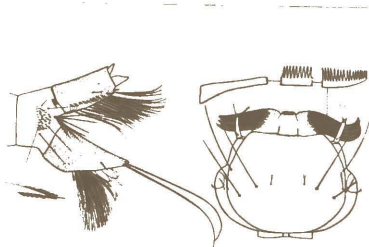
The distinguishing factor here is its high siphonal index of between 8-11. The larva itself is greyish-brown and has been recorded in tree-holes by a few other people. The adults do not have any striking feature as they are small and dark brown in colour. They however have basal bands on the abdomen. It was found both in the tree-holes and the tin cans and water receptacles in this survey.

12) Culex (Neoculex) horridus Edwards



The siphon of the larvae is exceptionally dark and long thus the index is about 12. The larvae are a dark grey colour and have been reported to breed in tree-holes by Hopkins (1952). The adult is also a dull species and is dark brown with bluish stripes of scales at irregular intervals down the thorax. The stripes may not even be conspicuous at all.

13) Culex (Lutzia) tigripes Grandpre'



This larva is rather large and brownish in colour. The mouth brushes are modified and rather prominent since they are predaceous on other larvae. The siphon (index 2) is very short rather like an Aedes species. A very common species in domestic pots and was never recorded in tree holes.

Adults are very large and appear brownish in colour. In most specimens there are pale spots on the femora and tibia of the fore and mid leg.

14) Toxorhynchites brevivalpis conradti Grünberg

The larva is conspicuous because of its large size and its usual red mahogany colour. The head is quadrangular and the siphon is also very short. The adult is very large (about 4 times larger than Aedes aegypti) and usually black but also has some blue or purplish metallic scales scattered on the thorax and legs. As it is a predator the larva is often seen devouring the other species in the tree-hole. It consistently breeds in tree-holes and rarely in domestic containers.



## APPENDIX 10

Example of Sampling chart for Danfa, 8th May, 1981

| No. of houses | No. and type of water containers | No. of containers with water | Degree of Infestation (no. of pots infested in brackets) | Ae/Cu.*                                 | Remarks  |
|---------------|----------------------------------|------------------------------|--|---|--|
| 2             | 4 d*                             | 4                            | ++ (2)   | <u>C. duttoni</u>                       | Pots outside                                   |
| 1             | 3 d,p                            | 3                            | -  |   |  |
| 2             | 2 d                              | 2                            | ++ (1)   | <u>Ae. aegypti</u><br><u>C. duttoni</u> | -  |
| 1             | 1 p                              | 1                            | -  | -                                       | pot covered                                    |
| 3             | 8 d,c                            | 8                            | ++++ (4)   | <u>Ae. aegypti</u><br><u>C. duttoni</u> | -  |
| 1             | 1 d                              | 1                            | -  |   | Coleopteran predators                          |
| 1             | 1 p                              | 1                            | -  | -                                       | "  |
| 1             | 2 d,c                            | 2                            | -  |   | Odonata nymphs                                 |
| 1             | 1 d                              | 1                            | -  |   | -  |
| 1             | 2 d,c                            | 2                            | +++ (2)  | <u>Ae.aegypti</u>                       |  |
| 3             | 11 d,c                           | 11                           | ++++ (9)   | "                                       | pots literally infested with <u>Ae.aegypti</u> |
| 1             | 1 d                              | 1                            | -  | -                                       | -  |
| 1             | 2 d                              | 2                            | + (1)  | <u>Ae.aegypti</u>                       |  |
| 1             | 1 d                              | 1                            | -  | -                                       | -  |
| 1             | 1 d                              | 1                            | -  | -                                       | water covered with kerosene                    |
| 2             | 6 d,p,c                          | 5                            | +++ (3)  | <u>Ae.aegypti</u><br><u>C. duttoni</u>  | -  |

## Appendix 10 Cont'd.

| No. of sites | No. and type of water container | No. of containers with water | Degree of Infestation (no. of pots in brackets) | Ae./Cu.*                                | Remarks  |
|--------------|---------------------------------|------------------------------|---|---|--|
| 1            | 2 d                             | 2                            | -   | -                                       | pots covered                                     |
| 1            | 2 d                             | 2                            | 1   | 1                                       | "  |
| 1            | 1 d                             | 1                            | ++ (1)  | <u>Ae.aegypti</u><br><u>C. tigripes</u> |  |
| 2            | 4 d,c                           | 3                            | ++ (2)  | <u>Ae.aegypti</u>                       |  |
| 1            | 2 d                             | 1                            | + (1)   | "                                       |  |
| 1            | 2 d                             | 2                            | ++ (1)  | "                                       | few empty tins showing signs of breeding nearby. |
| 1            | 2 d,c                           | 2                            | +++ (2)   | "                                       | plenty of organic debris in pots                 |
| 1            | 2 d,c                           | 2                            | -   | -                                       | -  |
| 1            | 2 d                             | 2                            | -   | -                                       | -  |
| 1            | 3 d,c                           | 3                            | +++ (2)   | <u>Ae.aegypti</u><br><u>C. duttoni</u>  | Some Hemipteran predators seen.                  |

\* d - metal drums

c - cement water receptacles

p - plastic containers

Ae. - Aedes speciesCu. - Culex species