LIFE-TABLE STUDIES IN CULEX SPECIES AND THE SUSCEPTIBILITY OF *CULEX QUINQUEFASCIATUS* SAY TO INSECTICIDES COMMONLY USED IN ACCRA.

A THESIS PRESENTED TO THE DEPARTMENT OF ZOOLOGY OF THE UNIVERSITY OF GHANA, LEGON, FOR THE DEGREE OF MASTER OF SCIENCE

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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.

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CONTENTS

1. INTRODUCTION

Interest in *Culex quinquefasciatus* Say (=fatigans Wied) has been increasing with the growth of urban areas in the tropical zones of the world because this mosquito is an important vector of bancroftian filariasis. When increased urbanization is accompanied by inadequate sewage treatment, conditions are ideal for proliferation of *C. quinquefasciatus*. No other species of mosquito has benefitted more from these acute sanitary problems than has *C. quinquefasciatus*. For its egg deposition and larval development, this species finds optimum conditions in water with a high degree of organic pollution.

Usually, mosquito larval and pupal surveys are made to provide guidance for control programmes. They can be designed for species, geographic and habitat distribution, parasitism and density.

In Ghana, Macfie and Ingram(1916) working on the seasonal distribution of the adult and larvae of mosquitoes in the various districts of Accra and Christiansborg concluded that *Aedes aegypti* and *Culex quinquefasciatus* are two dominant species but that *A. aegypti* was more common. Earlier, Graham

(1910) had studied the mosquito larvae found in water - receptacles at Lagos, Nigeria and found that a seasonal variation in numbers was shown to occur, but the causes were obscure. In this study, 2 active natural enemies of mosquitoes were found to exist. One natural enemy of mosquito larvae was *Culex tigripes*. The other was a small active surface-feeding fish *Haplochilus grahami*. This fish has a great capacity for populating flooded land by leaping from one pool to another. Catfish, however, preys on these fish.

In recent years, many basic studies on various aspects of *C. quinquefasciatus* population biology and disease relationships (i.e. filariasis) were initiated in Rangoon, Burma. The results of these studies were reported by de Meillon *et. al*-(1967). More recently, Chinery (1965, 1968a, 1968b) studied the mosquitoes in Accra with emphasis on their breeding places in relation to the mosquito control in an urban environment. He found that proliferation of *C. quinquefasciatus* (=fatigans) is due mainly to urbanization associated with the use of insecticides in preference to conventional sanitary measures. The most recent study on pre-adult population of *C. quinquefasciatus* in West Africa was conducted by Subra (1970), Patterson *et. al*-(1970). They studied the

seasonal variation of the population. Weidhass *et al.* (1971, 1973) also studied *C. quinquefasciatus* in an effort to suppress and eliminate the species using sterile males.

Referring to the previous studies in Accra, one observes that life-table studies and other quantitative studies on the population dynamics are lacking. It is known that the quantitative determination of mosquito larval abundance is a primary requirement of both mosquito control and research programmes. Generally, studies on mosquito dynamics are deficient on two accounts (Anon, 1968):

1. There are few 'adequate studies' of total numbers of eggs, larvae, pupae and adults in any sample.
2. The many effects of the environment on survival and reproduction have not been fully explored, still less adequately quantified.

One aim of entomologists is to develop technologies that will give the required degree of control most effectively, efficiently and economically. Such an aim implies that the control of diseases caused by mosquitoes should be based on the management of total populations rather than the continual reduction of high density populations at times when the insect or disease becomes a problem. In most cases,

it is possible to visualize the way in which a control technique will act on an insect population. However, the development of the potential of new or integrated approaches to control is less available.

As a contribution to planning integrated control measures, scientists have in recent times relied on life-table construction. The purpose of this is to summarize the survival and mortality rates of a population. Its application in recent times is found in agricultural and forest entomology (Morris 1963 , Southwood 1966, Varley and Gradwell 1970), and in fisheries biology (Ricker 1944, 1948, Wohlschlag 1954, Beverton and Holt 1957). Only recently has it been applied to mosquitoes (Lakhani and Service 1974, Service 1971, 1973, Southwood *et. al.* 1972).

Varley and Gradwell (1970) emphasized that the most instructive life-table will usually be based on the continuous and intensive study of a population in a single habitat, not by sampling different populations in a number of similar habitats in different years.

Where sampling is for life-table construction, differences in sensitivity of larval instars to disturbance produce biased samples. The 'enclosure method' whereby a given area is enclosed and all the larvae contained in the

area removed as practised by Cambournac (1939), Bates (1941) and Goodwin and Eyles (1942) are more suited to the study of extensive areas of shallow water with much vegetation, where larvae are numerous and evenly distributed.

In the types of breeding site indicated, this method is difficult to perform, because the larvae accumulate along the 'shore line' and not in the open area of the water habitat. The method used by Christie (1954) for recovery and enumeration of Anopheles gambiae from pools is however quite accurate and efficient and it shows that about 95% of the larvae of all stages except the first are recovered.

In general, the specimen-collecting devices used in qualitative and quantitative studies are the same (reviewed by Bradley and Goodwin, in Boyd 1949) but, where in qualitative work the specimens collected are most frequently in themselves the end-goal, the number of organisms taken per unit of effort or area is important in quantitative studies. Additionally, quantitative surveys methods differ in that a sampling design and a mathematical model for data analysis must be developed. In some cases it is also required that a method be developed for determining the numerical relationship between the specimens collected and total population size.

In connection with quantitative considerations, Andrewartha (1961a) recognizes two types of population densities. If it is possible to count or estimate all the animals in an area, the results are spoken of as the *absolute density* of a population. Where the size of a population is known only as a ratio to the size of another population either in time or space, it is said that the *relative density* is known.

In order to understand the factors that determine mosquito numbers, knowledge of the effects of environment upon survival, fecundity and dispersal is necessary. The data required are the total numbers of eggs, larvae, pupae and adults, in the area under study at different times, together with an analysis of environmental factors. Changes in numbers are then related to changes in environment. The analysis of such data is the subject of a paper by Hayes and Hsi (1975).

The sampling of larval density should aim at roughly estimating the relative density for quantitative evaluation. For this reason, the relative abundance of larvae of a particular species at different places can be determined, provided that the methods of sampling are standardized as far as possible. From experience by WHO, (Anon, 1975a)

the number of larval dips should be standardized as units of 10 dips or multiples of 10 dips (i.e. 20, 30, etc.) per capture station depending on the density of larvae. The most recently designed larval trap (Service, 1981) is very efficient and may replace other aquatic light traps. Probably this is because the mosquito larvae and pupae easily get attracted to the two ends of a cylinder within which the "Cyalume" chemical lightstick is suspended. It is therefore hoped that this light trap may be very useful for future work on Life-Table.

Quantitative approach to Life-Table studies is very important in larval control. If the numbers of each stage (e.g. eggs laid, eggs hatching, larvae, pupae and emerging adults) in a population are counted, and the logarithm of each number subtracted from that for the preceding stage, the results (the 'natalities' over the different age intervals) are called K-values. The sum of the K-values gives the total 'mortality' for the generation (Southwood, 1978).

When a series of Life-Table are available for successive generations of a population, the quantitative relationships of such K-values to population fluctuations, to population density, and to various environmental factors may be determined. This involves the quantification of significant

environmental factors as they change throughout the period of study. The objectives of such a Life-Table analysis make possible the recognition of

(1) Environmental factors that are important for the prediction of population fluctuation and

(2) the relationship of mortality (and dispersal) and each stage of the life cycle, and of natality, to population density.

Knowledge of this relationship is essential for building a model of the way in which numbers are determined. Thus information derived from this type of analysis provides the basis for the study of population dynamics. Studies of the effects of environmental factors on the mosquito throughout its life-cycle are also important.

In this study, the sites at Malam (plate A) and Nima (plate B) were selected for the following reasons: Nima drain is one of the most polluted areas in Accra, with human and animal excreta, and the breeding site, apart from proximity to Legon is also permanent throughout the year. What is more, it is an area noted for the breeding of *Culex quinquefasciatus* (=fatigans). The pond at Malam on the other hand, is an isolated area and inaccessible to the general public. The water is free from organic pollution, and also permanent throughout the year. Finally, the two

sites were free from exposure to pesticides over the period of study. Also inhabitants of the 2 sites are of the same ethnic groups (Hausas). However, while Nima drain is used for sewage disposal, there is improved sanitation at Malam. Therefore, there is a vast contrast between the two sites. The first aim therefore is to compare the incidence of *C. quinquefasciatus* (=fatigans) in the two sites. Secondly, it is the aim of this study to find the other mosquito species occuring with *C. quinquefasciatus* in the two sites.

The physico-chemical nature of the breeding sites was investigated with a view to determining the best time to control the vector - thus reducing its mean density below the Economic Threshold.

Since there has been little publication on insecticide susceptibility tests on mosquitoes of Accra, it was also considered worthwhile to study the susceptibility of *C. quinquefasciatus* to some insecticides for comparison with levels obtained elsewhere.

Even though this project of 12 months' duration is not long enough to confirm the seasonal fluctuation, it is however, hoped that it would serve as a guideline for future work. Furthermore, the work as a whole is extensive -

covering many aspects --but the section of Life-Table studies, seasonal fluctuation and insecticide susceptibility tests are topics of great interest and much quantitative work has been carried out.

FIELD WORK

1.1 Description of Study Sites - Malam and Nima.

Malam

Locality: This area is shown by the arrow on the map fig. 1. The pond in plate A is about 100 metres from the Accra-Winneba road, and about 8 km from the sea. It is an open grassland and the dominant littoral vegetation is *Sesuvium portulacastrum* (Portulacaceae). Others are *Bothriochloa bladhii* (Gramineae) and *Mariscus dubius* (Cyperaceae).

The study site is a pond which has been artificially created as a result of an abandoned quarry by the Brick and Tile Division of GIHOC. It is an isolated place where there are 6 other such ponds, but only the selected one is infested by mosquitoes. This is probably due to the fact that the other ponds are infested by predators such as guppies, *Poecilia reticulata* and tadpoles. There are other predators in the pond under study, however, but not guppies and tadpoles which are more efficient predators. Another reason may be due to the fact that the efficient predators being carried by floods from bigger ponds and a nearby lagoon during the rainy season are blocked by the heap of soil which separates the pond (plate A). On the other hand, the

other ponds are often left exposed to the direction of the nearby lagoon.

Even though, the pond is not very rectangular in shape, the length is 23.5 metres and the width is 7 metres. The surface area is 165m^2 (approx.) There is a small pocket at one side. Strong wind normally blows from West to East along the direction of Winneba to Accra and the mosquito larvae are always concentrated at one portion - where the samples are normally taken - as indicated on plate C. There is a random distribution of larvae when population increases and uniform distribution when the population decreases.

A scum is sometimes formed on the water surface where sampling is normally taken. Current from the sea is obstructed by the heap of soil from the dug-out pond.

The pond is an open place without tall trees, and there is no shade, no pollution and the water is permanent - throughout the year.

Nima

Locality: This area is shown by the arrow on fig. 1.

The Nima drain as shown in plate B is a permanent drain which is one of the most polluted areas in Accra. All sorts of wastes such as sewage, human excreta, rubbish, empty tins

and useless furniture
and cans are dumped into the exposed drain.

The drain is a stream starting from the Airport Residential area and flowing to Asylum Down. The pollution starts from Accra Girls' Secondary School.

The drain is about 5 metres wide (about 7 metres at some parts), 0.5 metre deep and fast flowing.

The dominant vegetation (littoral) along the drain are:

1. *Alternthera sessilis* (Amarantheceae)
2. *Sida ovata* (malvaceae)
3. *Ipomoea osarifolia* (convolvulaceae)
4. *Cucumeropsis edulis*,
5. *Eleusine indica* (Gramineae)
6. *Cynodon dactylon* (Gramineae)

There is a dense algal mat on the surface of the sheltered areas of the drain.

Even though this is a fast flowing drain, it is slow at some parts - especially along the bank. Larvae normally concentrate along the algal mats on the surface in a compound distribution because there are clumps of individuals, thus conforming to contagious distribution. The clumps themselves have random distribution. However, changes in density or life stages of the population causes changes in the distribution pattern - to random distribution.

PORTION OF 1:250,000 SHEET

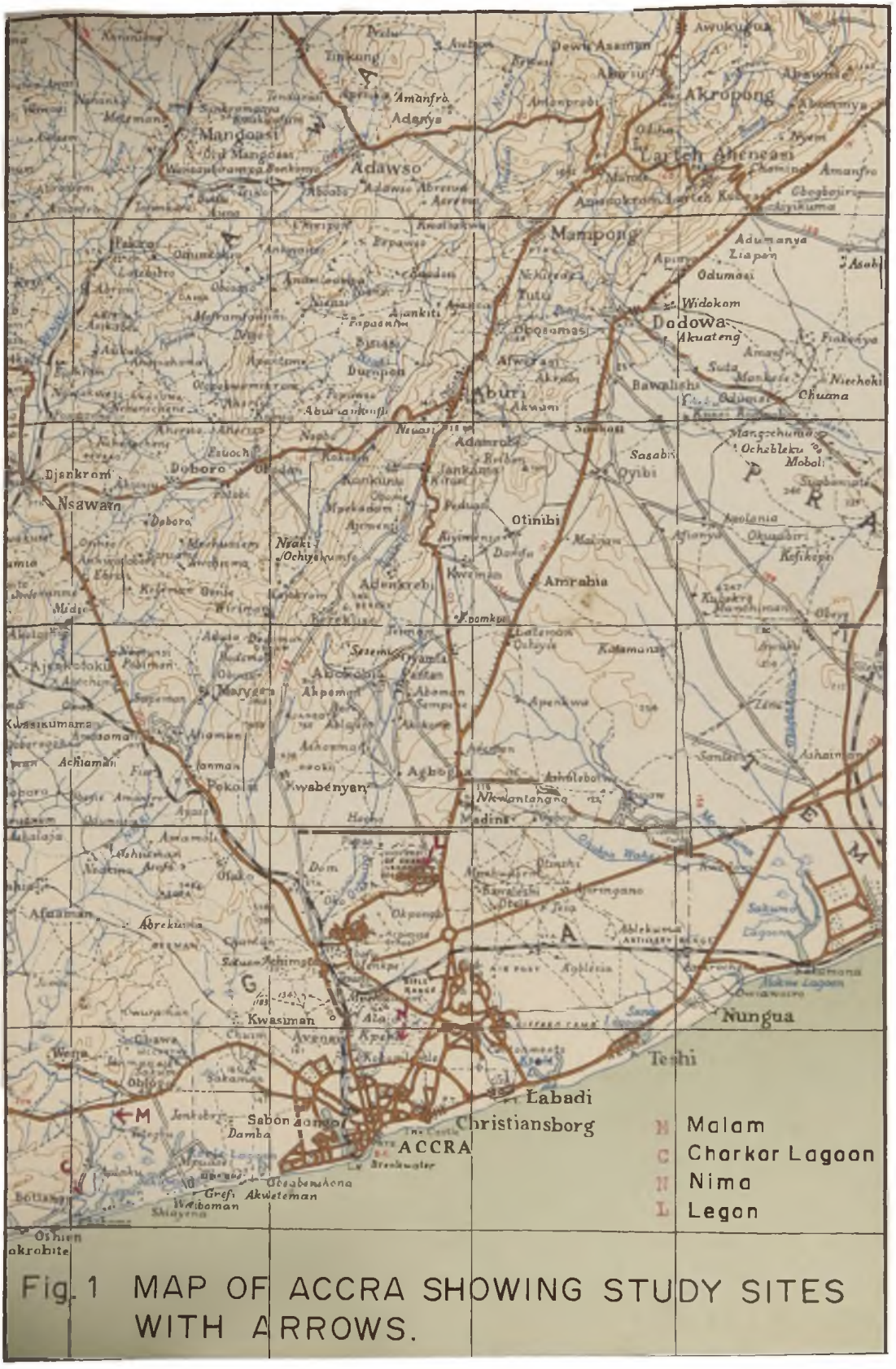

Fig. 1 MAP OF ACCRA SHOWING STUDY SITES WITH ARROWS.

Plate A: Study Site at Malam (A pond)

Plate B. Study Site at Nima (A drain)

Plate C. Mosquito larval sampling with net at Malam.

Plate D. Mosquito larval sampling with ladle at Nima.

1.2 Climate of Accra Area

The main rainy season is from April to July but there are some minor rains in March, October and November. During the 12 months under consideration, the total annual rainfall was 731.5 mm. The mean relative humidity at 0900hrs and 1500hrs was 81% and 69% respectively.

Data for the past 10 years (1970-79) in Accra show that the total annual rainfall was 795.2mm. The mean annual temperature was 27^{o}C and the mean relative humidity at 0900hrs and 1500hrs was 81% and 69% respectively.

Unfortunately, the climatological data of Weija the nearest station to Malam was not complete. However, for the periods of 1970-77, the mean monthly temperature was 25.9^{o}C, and the mean monthly relative humidity was 84%. The mean relative humidity at 0900hrs and 1500 hrs was 84% and 72% respectively. The total annual rainfall was 886.4mm.

1.3 PESTICIDES THAT HAVE BEEN USED IN ACCRA

Kerosene is one of the earliest hydro-carbons used in urban areas such as Accra. Apart from kerosene, gas oil and petrol constantly drain from filling stations, and fitting workshops, [illegible] into the gutters.

Dieldrin was introduced in the early 1960s. Its chemical name is 1,2,3,4,10,10-hexachloro 6,7 epoxy 1,4,4a, 5,6,7,8, 8a Octahydro exo 1,4, endo 5-8 dimethanonaphthalene (HEOD). In the late 1960s Sheltox was introduced. Sheltox contains the powerful volatile shell insecticide - Vapona to kill flying insects rapidly. Vapona is used directly in warehouses for domestic use. but is normally mixed with kerosene./ The chemical name for Vapona (Dichlorvos) is 2,2-dichloro vinyl o, o-dimethyl phosphate (DDVP). Other organochlorines used effectively are Endrine and Aldrine (soil insecticide) and Lindane (-BHC).

Aldrin (HHDN): 1,2,3,4,10, 10-hexachloro-1,4, 4a,5,8, 8a-hexahydro - exo - 1,4- endo 5,8 - dimethanonaphthalene. It is used for foliage spraying against insect pest on crops. It is formulated as dust, emulsion or liquid. Again it is used as a wood preservative and a soil insecticide. Lindane (Gamma-BHC): gamma-1,2,3,4,5,6-hexachlorocyclohexane. DDT has also been widely used. DDT: Dichloro-diphenyl trichloroethane could be used as 5% DDT dust, as foliage insecticide.

The organophosphates used are Gadona: Tetrachlorvinphos 2-chloro - 1 - (2,4,5 - trichlorophenyl) Vinyl dimethyl phosphate. It is formulated as a dust, and wettable powder and used for foliage spraying on crops. Also used as a space spray against storage pest. It is used against flies in animal houses, and as a 3% dust for body application against ecto-parasites in poultry. Phosdrine has also been used against mealy bugs. Its chemical name is Menvinphos - Cis isomer of methy 3 - (Dimethyloxy phosphinyloxy) crotonate. Gadona is used as 3% dust.

The carbamates used is phostoxine: This is a mixture of Aluminium phosphide and Ammonium Carbonate. It releases phosphine (pH3) gas on contact with moisture. It is used for disinfestation of stored products and processed food.

The use of all these chemicals contribute to the resistance of all vectors of medical importance that breed in gutters and stagnant water.

The use of chemical pesticides is today, the indispensable requirement for the control of various diseases. However, problems are encountered in their use, e.g. vector resistance, and ecological upsets. To advise on pesticide quality control in order to avoid these problems, the WHO Expert Committee on Vector Biology and control met in Geneva

from 29th November to 5 December 1977. (Anon, 1978) The Committee was asked to study pesticide specifications, and to provide guidance for improving the specifications of new types of formulations and active ingredients. The Committee recommended for the development of new insecticides with emphasis on field tests on efficacy and safety. It also recommended close collaboration with the Food and Agriculture Organization of the United Nations (FAO) in developing information Service in Pesticide standards.

Temephos, particularly as 1% on Sand, is used extensively against *Aedes aegypti* which breeds in containers of clean and potable water.

In its 19th report (Anon 1970) the WHO Expert Committee on Insecticides noted the development of synthetic pyrethroids, which were then looked upon as replacements for the natural product for use in aerosols for space treatment. Since that time, the situation has been completely changed by the discovery of pyrethroids that are both highly insecticidal and much more stable on exposure to light and air. They can be used for the control of agricultural and public health pests in situations where natural pyrethrum and earlier synthetic pyrethroids would never have been considered.

2. MATERIALS AND METHODS

2.1 LIFE TABLES

Objectives: To regularly sample populations to try to construct Life-tables and to evaluate different sampling techniques such as light and sticky traps.

Laboratory: *Culex fatigans* (= *quinquefasciatus*), from the field are made to breed in the laboratory. Females are given anaesthetised rats for blood meal. Egg rafts laid by the female adults are counted into beakers containing water. The beakers are always kept in cages

Farex and Cerelac are used as larval food. The water in the larval beakers is changed daily to avoid contamination. Daily counts of the dead larvae are made and recorded in a tabular form; and the dead ones eliminated from the beakers.

Numbers of the various stages are also recorded (Tables 10 and 11). The experiments were repeated several times in replicates and the results recorded.

Field: Apart from weekly samplings for one year at Malam and Nima (Tables 19 & 20) daily samplings were made at Legon, (Table 4)
(Table 3), Chorkor Lagoon and also at Nima (Table 9) and Malam (Tables 6 and 7), to construct life-tables.

2.2 Weekly Samplings

Material and Method

A pond net was constructed very simply using a ring of iron wire 38.5 cm. in diameter to which a bag was attached. A round hole was cut in the bottom of the bag and a transparent plastic cylinder (2.0 cm. diameter, 9 cm. long) was attached. A long iron handle was attached to the ring.

During collection, the larvae are washed into the tube which can then be emptied directly into a bottle.

When collecting larvae, the net is held at an angle and skimmed rapidly through the surface water near emerging or floating vegetation (Plate C). The use of nets permits the sampling of large areas of water in a relatively short time. The long handle facilitates collection from under high banks and other inaccessible situations.

A total of 10 dips are made during each of the weekly sampling days of the week. Each sample is transferred into a separate bottle (containing 70% alcohol) to be counted later in the laboratory.

Counting: Counting of individual larvae was made and recorded by instar. With the increasing number of individuals, it became too difficult to count. The sample was mixed in 100mls of 70% alcohol to ensure a homogenous distribution. Ten mls of the sample in the solution was counted

at a time. The correct number was then calculated after measuring the total volume in a measuring cylinder.

Mosquito species recorded:

Mosquito species recorded are: *Culex decens*, *C. duttoni*, *C. quinquefasciatus*, *C. thalassius*, *Aedes albocephalus*.

Other aquatic life.

Aquatic animals, apart from mosquitoes, are: 1 Dragonfly nymph, 2 Dragonfly adult (Libellulidae), 3 Notonecta, 4 Gerris, 5 Hydrometra, 6 Nepa (Nepidae), 7 Rhagovelia (Vellidae), 8 Coenagridae, 9 Cybister spp. larva, Cybister spp. adult; 10 Tadpoles.

Material and methods

A white plastic container of 9.2 cm. (diameter) to which a long wooden handle (like a ladle) is attached is used for collecting larvae from the drain. The 0.320 litre dipper is normally immersed in the breeding places at an angle of 45° (Place D). The surface water will flow into the cavity but care is taken not to fill this completely as otherwise some larvae will be washed out (if a dipper is immersed too slowly, the larvae are disturbed and go to the bottom with the result that many escape collection). There is an interval of 2 - 3 minutes between each dip to

allow stage III and IV larvae and pupae to return to the surface. 20 dips are normally made into separate bottles and later sent to the laboratory for counting.

Dipper types and dipping techniques are reviewed by Bradley and Goodwin (in Boyd 1949)

Mosquito species recorded

Mosquito species recorded are: Culex decens, C. duttoni. C. thalassius, C. tigripes, C. quinquefasciatus and Aedes aegypti.

Other aquatic life

The aquatic animals, apart from mosquitoes are 1. Tadpoles, 2. Guppies Paecilia reticulatus, 3. Syrphidae, 4. Tetanoceridae, 5. Chironomidae (Chironomus) and 6. Notonectidae (Notonecta).

2.21 Light traps:

Aquatic light trap

Inverted plastic cones are fitted to each end of a tube (inside which has been painted white with oil paint to reflect more light) "Velcro" is stuck and sewn round edge of plastic cone the apex of which has an outlet (hole) for larvae to pass through. Again "Velcro" is stuck on inside of tubes, and cones can be fitted into tubes and easily removed.

To ensure firm sticking, holes were drilled round the ends of the cylinder, and the velcro sewn to it with wire.

Chemical lightstick procedure:

The lightstick "Cyalume" is bent to break the inner glass and the tube shaken. One end of the plastic tube is cut off and the contents poured into a suitable glass tube. The tube is suspended in the middle of the cylinder. Two Betalights are glued to each end of a plastic cylinder and suspended in the tube with the lightstick Fig. 2.

The trap is submerged under water.

Light Trap

Under laboratory conditions, light trapped 95% of *Culex thalassius* larvae and pupae. It is mostly effective against the larvae but pupae are also attracted to the light (Table 21).

In the laboratory, the sink was filled with water and large numbers of larvae and pupae introduced. The light trap was introduced and left over-night when it attracted almost all the larvae, leaving a number of the pupae on the surface of the water.

The light trap was used at Malam on the 28th May 1981 and about 18,500 larvae were trapped within a period of 12 hours (7 p.m.-7a.m.). The number trapped would however

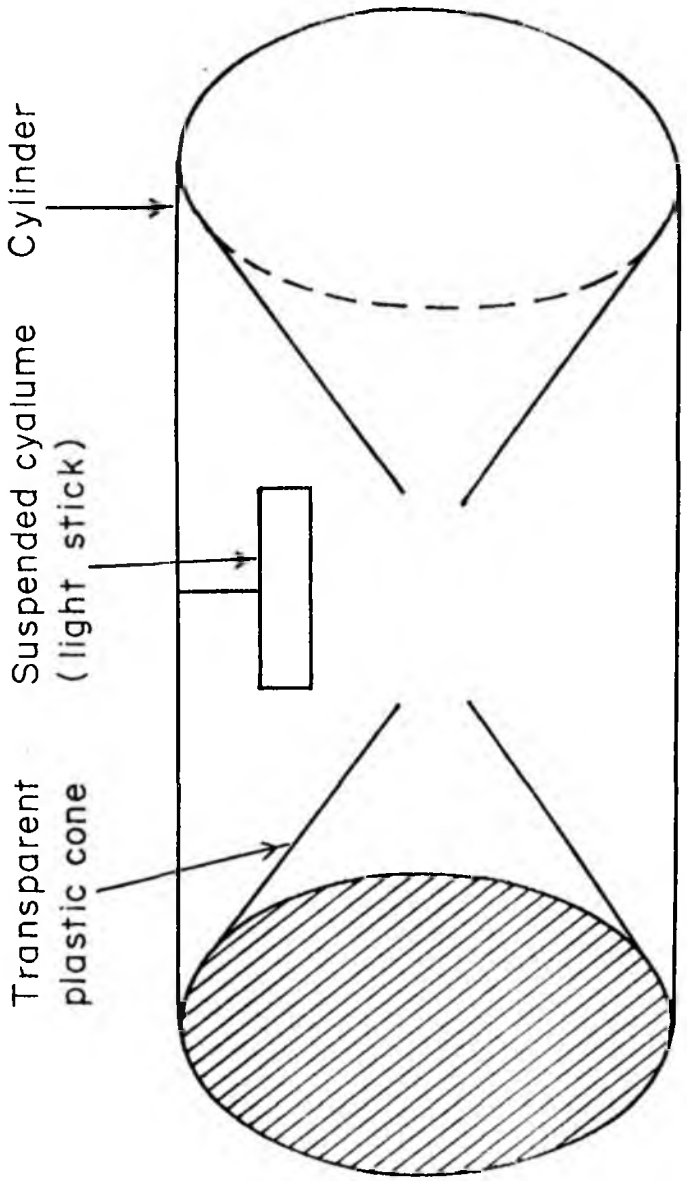

Fig. 2 DIAGRAM OF LIGHT TRAP USED IN THE POND AT MALAM AND CHORKOR LAGOON.

depend on the abundance of larvae in the pond. On the 19th June 1981 about 3,000 were caught in the same pond. At this time, the number of larvae had decreased in the pond.

The light trap was also used at Chorkor Lagoon from 6a.m.-8p.m. on the 10th and 11th July 1981. The catches were, 1168 larvae and 208 pupae on the first day and 1,580 larvae and 453 pupae on the second day. Results obtained by comparing the effectiveness of the Light and Sticky traps on the field are found in (Table 23).

2.22 Sticky Trap

Laboratory: The Rat and Mouse varnish was used in the laboratory. 5 large beakers (500mls) were filled with water. 50 larvae and 50 pupae were introduced into each. Into each beaker was introduced the varnish and a carpet of sticky layer formed on the water surface.

Observations show that all the pupae were trapped almost immediately when they came to the surface. The larvae were not caught immediately because larvae are active swimmers. The 1st and 2nd instar larvae which rely more on cuticular respiration were actively swimming in the water and did not come to the surface and therefore were not trapped immediately.

Results are found in Table 22.

Field: The sticky trap (Varnish) was used in the field at Chorkor. This was done by coating a plastic sheeting 30.0cm by 16.0cm with the varnish and made to float on the water surface. A carpet of "Varnish Scum" was formed on the water surface, and all the pupae were trapped on the water surface. Some larvae were also trapped, but the sticky trap was found not effective for eggs and 1st and 2nd instar larvae (which also rely on cuticular respiration).

2.3 Physico-Chemical Characteristics of Soil and Water.

Determination of Salinity

The aim of this study was to compare the salt content and site preferences of mosquitos at the two areas - Malam and Nima. Salinity is expressed in terms of chloride (Cl^-)

Materials:

- Graduated Cylinders of 10ml.
- Weak Silver nitrate (analytical grade) solution 9.58g. per litre.
- Strong silver nitrate (analytical grade) solution 47.9g. per litre.
- Potassium chromate solution, 5%.
- Brown bottles with droppers for silver nitrate solution.

Procedure: Anonymous (1975b)

To 4 ml. of water from the breeding place in a graduated tube, 3 drops of potassium chromate are added and mixed.

The silver nitrate solution (weak or strong according to salinity) is added in the tube in small quantities and mixed well with the water after each addition. This is done by closing the opening with a rubber stopper and inverting the tube 3-4 times.

A red precipitate persisting after shaking indicates the end point of the reaction. The amount of reagent (silver nitrate) added is read on the graduations of the tube.

PHYSICO-CHEMICAL CONDITIONS OF THE POND AND DRAIN

The data Table 26 shows analysis of the water and soil samples.

Methods used: pH of the water samples was taken electrometrically using a soil: water ratio of 1:2 and soil:0.01 calcium chloride solution ratio of 1:2.

Organic carbon was determined by the wet - combustion method of Walkeley-Black and Organic carbon converted to organic matter using a factor of 1.72.

Sodium in the water sample was determined by the flame-photometer and in soil after extraction with neutral N NH_4 OA_c solution.

The dissolved 0_2 was determined by using the WINKLER METHOD, while chlorine was determined by WHO standard method (Anonymous 1975b).

DETERMINATION OF OXYGEN CONTENT

THE WINKLER METHOD

Material and Method: (1) From a 250cc. sample bottle containing sample to be analysed, remove a stopper and by means of long narrow volumetric pipette, 1cc. of maganous sulphate solution (Winkler) 1) is added well below surface of water. In the same way, 1cc of KOH-KI solution (Winkler II) is added. Precipitate forms immediately.

(2) Stopper is replaced and sample mixed by inverting bottle several times. Precipitate is allowed to settle for a few minutes.

(3) 1cc. of Conc H_2SO_4 is added to release the iodine. The bottle is inverted several times for proper mixing. Sample is allowed to stand for 10 minutes.

(4) 200cc. of sample is transferred to conical flask, and titrated rapidly with N/40 sodium thiosulphate solution until iodine colour in the sample has been reduced to pale straw colour. At this stage, a few c.c. of starch solution is added and continued rapidly but continuously until blue colour first disappears (end of titration).

2.4: Insecticide Susceptibility Tests

Material and Method.

(a) For a complete test with one insecticide, sufficient larvae were collected from the field in order that about 300 individuals of the same species of *Culex quinquefasciatus* Say (=fatigans Wied) were selected. They were in their 4th instar and were retained in the water in which they were collected until selected for testing. Larvae showing abnormalities (for example a fuzzy appearance of parasites on the body surface), were discarded. Lots of 25 larvae were distributed in each of 12 small beakers, each containing 25mls. of water. Their transfer was effected by means of an eye-dropper. During the process, they were rinsed lightly in clean water.

(b) Into each of 12, 500-ml beakers, 225ml of water were placed. The vessels were such that the depth of water was about 4.5cm. Pure water, free from chlorine and organic contaminants (from upstream of the breeding site) was used. The average temperature of the water(H_2O) was approximately 27°C.

(c) The test concentrations were prepared by pipetting 1 ml. of the appropriate standard insecticide solution (DDT, DIELDRIN and LINDANE respectively) under the surface of the water in each of the glass vessels and stirring vigorously for 30 seconds with the pipette. In preparing the series of concentrations, the most dilute was prepared first. There were two replicates at each concentration and two control

replicates.

(d) Within 15-30 minutes of the preparation of the test concentration, the mosquito larvae were added to them by tipping the contents of the small beakers into the vessels.

(e) After a period of 24hours, mortality counts were made. In recording the percentage mortalities for each concentration, the moribund and dead larvae in both replicates were combined. Dead larvae are those that cannot be induced to move when probed with a needle in the siphon or the cervical region. Moribund larvae are those incapable of rising to the surface (within a reasonable period of time) or showing the characteristic diving reaction when the water is disturbed;

(f) Larvae that have pupated during the test were discarded. If more than 10% of the control larvae pupated in the course of the experiment, the test was discarded. Tests with a control mortality of 20% or more were considered unsatisfactory and therefore repeated.

(g) Additional concentrations were prepared both above and below .004 ppm. Additional intermediate concentrations were prepared by diluting a portion of a standard solution with pure toluene (e.g. a concentration of 0.01 ppm. may be obtained by diluting the 0.02 ppm. standard with an equal quantity of toluene before taking the 1 ml. for addition to

the water in the beakers)

(h) 4 replicates were performed with the same population of mosquito larvae, and this was used for constructing a baseline-susceptibility. The results were recorded in Tables 28,29 and 30.

To check for resistance, a discriminating dosage at 1 ppm (Fig. 14) was made and their values recorded (Table 34,37,40). These values were checked in accordance with the WHO larval surveys (Anon 1975a), and results recorded (Tables 35,38,41). The survivors were reared to adults in the Laboratory and their Larvae ("F_2") tested again for susceptibility to DDT, Dieldrin and Lindane respectively (Tables 36,39,42). Calculations for mortalities were made using ABBOTT'S FORMULA. (Tables 28 to 30 and Tables 34 to 42).

The values from this experiment were compared with the results of the WHO Test for susceptible Culex fatigans Wied (=quinquefasciatus Say) larvae obtained from Fiji, (Burnett & Ash 1961) and the values recorded in Table 43.

3. RESULTS.

3.1: Life Tables

The following Tables and graphs are the results obtained from the experiments and field data collection. The data in Table 1 show total instars from the various sites.

Table 1: INSTAR NUMBERS, DURATION AND LOGARITHMS OF NUMBERS/DURATION OF IMMATURE STAGES OF MOSQUITOES AT VARIOUS SITES.

Locality (SITES)	Description	I	II	III	IV	P
NIMA (TABLE 7)	Instar numbers	20082	15451	10894	680	10130
	Instar duration	3	2	3	2	3
Culex quinquefasciatus	Larval Nos Instar duration	6694	7725.5	3631.3	340	3376.6
	Log larval No. Instar duration	3.8257	3.8879	3.5600	2.5315	3.5284
CHORKOR LAGOON (TABLE 4.) *C. thalassius*	Instar Nos.	33552	23087	13948	13609	133489
	Instar duration	2.5	2	2.5	2	2.5
	Instar Nos. Instar duration	13420.8	11543.5	5579.2	6804	53395.6
	Log Instar Nos.	3.1277	4.0622	3.7466	3.8328	4.7274
LEGON (TABLE 3) (Fig 10) *C. duttoni.*	Instar Nos.	410	348	269	226	130
	Instar duration	3	2	3	2	3
	Instar Nos. Instar duration	136.66	174	89.67	113	43.33
	Log Instar Nos. Instar duration	2.1358	2.2405	1.9526	2.0531	1.6368
MALAM (TABLE 6) *C. thalassius*	Instar Nos.	47602	32864	24770	15985	2013
	Instar duration	2.5	2	2.5	2	2.5
	Instar Nos. Instar duration	19040.6	16432	9908	7992.5	805.2
	Log Instar No. Instar duration	4.2797	4.2156	3.9959	3.9027	2.9059

Table 2 ; INSTAR NUMBERS, DURATION AND LOGARITHMS OF NUMBERS/ DURATION OF IMMATURE STAGES OF MOSQUITOES AT VARIOUS SITES*

LOCALITY & SPECIES	DESCRIPTION	I	II	III	IV	P
NIMA (TABLE 9) (days 2-6) *Culex quinque-fasciatus*	Instar Nos.	17069	12136	8017	4765	4961
	Instar dura.	3	2	3	2	3
	Instar Nos. Instar dura.	5689.67	6068	2672.33	2382.5	1653.67
	Log Instar Nos Instar dura.	3.7550	3.7830	3.4269	3.3770	3.2184
CHORKOR LAGOON (TABLE 4) (days 1-5) *C. thalassius*	Instar Nos	4006	3391	3923	2538	1891
	Instar dura.	2.5	2	2.5	2	2.5
	Instar Nos Instard dura.	1602.4	1695.5	1569.2	1269	756.4
	Log Instar Nos Instar dura.	3.2048	3.229	3.1957	3.1035	2.878
Chorkor Lagoon (TABLE 4) Fig. 9 (days 7-11) *C. thalassius*	Instar Nos.	8087	5733	4327	2740	1652
	Instar dura.	2.5	2	2.5	2	2.5
	Instar Nos. Instar dura.	3234.8	2866.5	1730.8	1370	660.8
	Log Instar Nos. Instar dura.	3.5098	3.457	3.2382	3.1367	2.820
CHORKOR LAGOON (TABLE 4) (days 15-19) *C. thalassius*	Instar Nos.	7972	7740	2659	3714	46117
	Instar dura.	2.5	2	2.5	2	2.5
	Instar Nos. Instar dura.	3188.8	3870	1063.6	1857	18446.8
	Log. Instar Nos Instar dura.	3.5036	3.5877	3.0267	3.2688	4.2659
MALAM (TABLE 6) (Fig.8) (day 5-15) *C. thalassius.*	Larval Nos.	36440	25096	18776	11878	1587
	Instar dura.	2.5	2	2.5	2	2.5
	Larval Nos. Instar dura.	14576	12548	7510.4	5939	634.8
	Log. Larval No. Instar dura.	4.1636	4.0986	3.8757	3.774	2.8026

* For graphical analysis, emphasis was laid on specific collecting days because it shows gradual trend in population reduction. For example day 2-6 at Nima means, from the second to the sixth day.

Table 3: No. of immature stages of *Culex duttoni* caught each day of 20 dips from larval habitat (pot hole) at Legon June 1981.

Collecting days	No. of larval instars (i-iv) & pupae (P) caught					Totals
	I	II	III	IV	P	
1	24	131	84	62	0	301
2	37	68	69	56	2	232
3	101	61	35	18	11	226
4	114	31	22	19	22	208
5	78	19	23	30	36	186
6	31	17	19	28	43	138
7	25	21	17	13	16	92
Totals	410	348	269	226	130	1383

Table 4: No. of immature stages of *Culex thalassius* caught each day * of 20 dips from larval habitat at Chorkor Lagoon.

Collecting days	No. of larval instars (i-iv) & pupae (P) caught.					Totals
	I	II	III	IV	P	
1	1820	1610	1039	302	55	4826
2	401	736	1275	874	251	3537
3	353	593	1073	680	201	2900
4	578	202	311	475	821	2387
5	854	250	225	207	563	2099
6	1647	913	768	287	39	3654
7	2997	2200	1429	473	8	7107
8	2217	1583	1306	718	2	5824
9	1262	815	579	403	299	3358
10	421	382	443	880	1109	3235
11	1190	753	570	266	234	3013
12	2724	1564	1174	796	569	6827
13	4751	1995	834	2053	4595	14228
14	4365	1751	263	1481	4084	11944
15	3168	5062	606	1259	21426	31521
16	2031	1352	1007	673	13434	18497
17	1745	752	644	1424	3633	8198
18	525	216	136	192	5879	6948
19	503	358	266	166	1745	3038
	33552	23087	13948	13609	58947	133489

* For graphical analysis, emphasis was laid on specific collecting days because it shows gradual trend in population reduction. For example day 1-5 means from the first to the 5th day.

Table 5: No. of immature stages of *Culex thalassius* caught each week of 10 dips from larval habitat at Malam.

Collecting Days	No. of larval instars (i-iv) and pupae (P) caught					Totals
	I	II	III	IV	P	
1	1285	909	763	586	62	3,605
8	5535	4062	2943	1747	177	14,287
15	476	308	225	128	107	1137
22	4620	3502	2266	1608	1810	11,996
29	687	598	415	274	4	1,974
Totals	12603	9379	6612	4343	2160	32,999

Table 6: No. of immature stages of *Culex thalassius* caught each day of 10 dips from larval habitat at Malam, (20-5-81)-(23-6-81). For graphical analysis emphasis was placed on days 5-15 because of uniform population reduction during this period.

Collecting days	No. of larval instars (i-iv) and pupae (P) caught					Totals
	I	II	III	IV	P	
1	1285	909	763	586	62	3605
2	2240	1556	1186	798	74	5854
3	3126	2171	1656	1115	138	8206
4	4511	3132	2389	1608	152	11792
5	6636	4608	3514	2367	321	17446
6	6201	4307	3284	2212	78	16082
7	5841	4083	3093	2057	152	15226
8	5535	4062	2943	1747	177	14464
9	4395	2845	2078	1182	395	10895
10	2923	1892	1381	787	86	7069
11	1871	1210	892	497	78	4548
12	1048	728	556	372	46	2750
13	927	645	491	329	88	2480
14	587	408	319	200	59	1573
15	476	308	225	128	107	1244
	47602	32864	24770	15985	2013	123234

Table 7: No. of immature stages of *Culex thalassius* caught each day of 10 dips from larval habitat at Malam. (3-6-81-22-6-81) Emphasis on day 5-18.

Collecting days	No. of larval instars (i-iv) and pupae (P) caught.					Totals
	I	II	III	IV	P	
1	476	308	225	128	107	1244
2	1280	906	760	646	61	3653
3	2306	1705	1232	741	74	6058
4	3439	2375	1745	1260	629	9448
5	6170	4285	3267	2203	656	16581
6	5368	3796	3189	2711	482	15546
7	5295	3893	2819	1687	239	13933
8	4620	3502	2266	1608	1810	13806
9	4294	2779	2021	1163	422	10679
10	3212	2230	1701	1145	102	8390
11	2428	1685	1285	867	205	6470
12	1596	1129	948	807	121	4601
13	1163	886	661	506	54	3370
14	831	609	441	261	26	2168
15	687	598	415	274	4	1978
16	531	385	263	151	48	1378
17	536	246	187	125	15	929
18	230	159	121	84	8	602
19	366	235	179	116	36	932
20	519	345	264	157	21	1306
	45167	32056	23989	16640	5220	122972

Table 8: Total Yearly instars, instar durations and logarithms of respective immature stages of *Culex quinquefasciatus* at Nima and Malam (Ref Tables 19 & 20).

Locality		I	II	III	IV	P
NIMA	Larval numbers	6964	7653	4980	2677	2290
	Instar duration	3	2	3	2	3
	Larval Numbers / Instar duration	2321.3	3826.5	1660	1338.5	763.3
	Log larval no/ Instar duration	3.37	3.58	3.22	3.12	2.88
MALAM	Larval numbers	12603	9382	6612	4345	2160
	Instar duration	2.5	2	2.5	2	2.5
	Larval numbers / Instar duration	5041.2	4691	2644.8	2172.5	864
	Log larval numbers/ Instar duration	3.70	3.67	3.42	3.34	2.93

Table 9: No. of immature stages of *Culex quinquefasciatus* caught each day of 10 dips per bottle of 20, from larval habitat at Nima.

Collecting days	No. of larval instars (i-iv) and pupae (P) caught.					Totals
	I	II	III	IV	P	
1	1443	2777	2128	1611	5016	12975
2	5538	3445	2202	1726	2127	15138
3	5959	4247	2892	1281	589	14968
4	3269	2465	1701	492	131	8058
5	1016	537	683	1070	1312	4618
6	1287	721	539	196	802	3545
7	1570	1259	749	425	153	4156
Totals	20082	15451	10894	680	10130	63458

Table 10: Life-table of immature stages of *Culex quinquefasciatus* showing numbers and their conversion to base 1000.

Expt.	NE	N_1	N_2	N_3	N_4	NP^1	NP	NA	Adult No. surviving
1	200	150	126	96	64	52	48	18	6
	1000	750	630	480	320	260	240	90	30
2	204	166	130	90	52	44	34	10	4
	1000	814	637	441	255	216	167	49	20
3	206	178	128	82	76	58	46	24	14
	1000	864	621	398	369	282	223	117	67
4	200	172	126	86	68	50	38	26	10
	1000	860	630	430	340	250	190	130	50
5	200	168	130	80	64	42	30	26	18
	1000	840	650	400	320	210	150	130	90
6	202	170	126	76	62	54	42	30	16
	1000	842	623	376	307	267	208	149	79
7	188	139	118	98	53	47	38	23	7
	1000	739	628	521	282	250	202	122	37
8	200	151	120	96	64	52	24	19	8
	1000	755	600	480	320	260	120	95	40
9	200	148	125	103	61	50	41	25	6
	1000	740	625	515	305	250	205	125	30
10	197	143	125	107	58	43	36	16	6
	1000	726	634	543	294	218	183	81	30
Total	10000	7930	6278	4584	3112	2463	1888	1088	473
Av.	1000	793	628	458	311	246	189	109	47

KEY: NE = Number of Eggs.
N_1 = Number of 1st instar larvae.
N_2 = " " 2nd " "
N_3 = " " 3rd " "
N_4 = " " 4th " "
N'_p = No. of pre-pupae "
N_p = " " pupae
NA = " " of Adults.

Table: 11 Life-Table for immature stages of *Culex quinquefasciatus* mean length of life is 4.84 days.

LINE	NE	N_1	N_2	N_3	N_4	N_p1	N_p	A
1. Population	1000	793	628	458	311	246	189	109
2. No. dying at intervals	207	165	170	147	63	57	80	
3. % Mortality factors of original	20.7	16.5	17.0	14.7	6.3	5.7	8.0	
4. Successive % mortality	20.7	20.8	27.1	32.1	20.3	23.2	42.3	
5. Successive survival	79.3	79.2	72.9	67.9	79.7	76.8	57.7	
6. Fraction survival	.793	.792	.729	.679	.797	.768	.577	
7. Log (Pop.)	3.00	2.90	2.66	2.49	2.39	2.28	2.04	
8. K-Value	0.10	0.11	0.13	0.17	0.10	0.11	0.24	

Total K-value (viz: ΣK-value)=0.96.

Table 12 Values for survivorship curve of *Culex quinquefasciatus* as found in Fig.4. Mean length of life 4.84 days.

X Age (days)	Age as % deviation from mean length of life	lx No. surviving at start of interval	d No. dying within age interval	100qx Rate of per 1000	e_x Mean Expectation at further life	T_x	L_x
0	-100%	1000	207	207	3.2095	3179.5	896.5
2	-58.7	793	165	208	2.8789	2283	710.5
5	3.3	628	200	271	2.5039	1572.5	543.0
7	44.6	458	147	321	2.2478	1029.5	384.5
10	106.6	311	63	203	1.0739	645	278.5
12	147.9	246	57	232	1.4898	366.5	217.5
13	168.6	189	80	423	0.7883	149	149.0
15	209.9	109	-	-	-	-	-

Table 13: Developmental time (days), and temperatures for immature stages of *Culex quinquefasciatus & C. thalassius*. June 1981.

Expt.	NE	N_1	N_2	N_3	N_4	N_p1	N_p	Larval development. Egg-to emergence	Water Temp. $^oC.$
1	2.5	3.0	2.5	3.5	2.0	1.0	2.0	16.5	26.5
2	2.2	3.2	2.2	3.0	2.0	1.0	1.5	15.1	27.0
3	1.4	2.5	2.0	3.2	2.0	1.5	2.0	14.5	27.0
4	2.0	3.0	2.0	2.5	2.1	0.9	2.5	15.0	27.0
Σ	8.1	11.7	8.7	12.2	8.1	4.4	8.0	61.1	27.5
$\bar{x}$	2.03	2.93	2.18	3.05	2.03	1.10	2.0	15.28	26.9
1	1.0	2.0	2.0	3.0	2.0	0.8	1.8	12.6	27.0
2	1.0	2.5	2.0	2.5	2.0	1.0	1.5	13.0	26.5
3	1.5	3.0	2.2	2.5	2.5	1.0	1.5	14.2	26.5
4	0.8	2.5	2.0	1.8	2.0	0.8	2.0	11.9	27.0
Σ	4.3	10.0	8.2	9.8	8.5	3.6	6.8	51.7	27.0
$\bar{x}$	1.08	2.5	2.05	2.45	2.13	0.9	1.70	12.93	26.75

KEY: NE = Number of eggs.
N_1 = " " 1st instar larvae
N_2 = " " 2nd " "
N_3 = " " 3rd " "
N_4 = " " 4th " "
N_p1 = No. of pre-pupae
N_p = " pupae
NA = No. of Adults.

Table 14: Daily records of life-table studies of immature stages of *Culex quinquefasciatus* surviving in the laboratory.

Age (days)	Numbers surviving				Totals	Average	No. to Base 1000
	Cage 1	Cage 2	Cage 3	Cage 4			
0	200	200	198	203	801	200.25	1000
1	172	186	198	203	759	189.75	948
2	154	148	145	157	604	151.0	754
3	149	134	138	157	578	144.50	722
4	132	129	132	140	533	133.25	665
5	128	127	131	135	521	130.25	650
6	105	110	108	120	443	110.75	533
7	96	103	108	112	419	104.75	523
8	68	72	89	96	325	81.25	406
9	64	61	72	83	280	70.0	349
10	56	51	72	83	262	65.50	327
11	52	50	58	65	225	56.25	281
12	44	41	49	65	199	49.75	248
13	42	41	49	54	186	46.50	232
14	32	25	36	52	145	36.25	181
15	29	25	34	38	126	31.50	157
16	27	20	25	29	101	25.25	126
17	14	18	23	25	80	20.0	100
18	14	23	19	20	68	17.0	85
19	12	14	19	18	63	15.75	79
20	10	10	15	12	47	11.75	59
21	8	10	11	12	41	10.25	51
22	8	10	10	10	38	9.50	47
23	5	8	8	7	28	7.0	35
24	4	5	6	5	20	5.0	25
25	3	4	5	4	16	4.0	19
26	2	4	4	3	13	3.25	16
27	2	3	2	2	9	2.25	11
28	1	2	1	2	6	1.50	8
29	0	0	0	0	0	0	0

Cage I

Table 15: Daily records for Life-Table studies of immature stages of *Culex quinquefasciatus* surviving in the laboratory.

Age (days)	E	I	II	III	IV	P_1	P_2	A	Totals
0	200								200
1		172							172
2		151	3						154
3		145	4						149
4		74	58						132
5		2	125	1					128
6			91	14					105
7			14	81	1				96
8			7	57	4				68
9			3	19	42				64
10				3	52	1			56
11				1	47	4			52
12					5	35	4		44
13						3	39		42
14							29	3	32
15							3	26	29
16								25	27
17								14	14
18								14	14
19								12	12
20								10	10
21								8	8
22								8	8
23								5	5
24								4	4
25								3	3
26								2	2
27								2	2
28								1	1
29								0	0

Cage 2

Table 16: Daily records for Life-Table studies of immature stages of *Culex quinquefasciatus* surviving in the laboratory.

Age (days)	E	I	II	III	IV	P_1	P_2	A	Totals
0	200								200
1		186							186
2		147	1						148
3		132	2						134
4		72	55						129
5		8	117	2					127
6			94	16					110
7			17	78	8				103
8			4	61	7				72
9			1	25	35				61
10				2	48	1			51
11				1	42	7			50
12					1	37	3		41
13							39		41
14							23	3	25
15							2	23	25
16								20	20
17								18	18
18								15	15
19								14	14
20								10	10
21								10	10
22								10	10
23								8	8
24								5	5
25								4	4
26								4	4
27								3	3
28								2	2
29								0	0

Table 17: Daily records for Life-Table studies of immature stages of *Culex quinquefasciatus* surviving in the laboratory.

Cage 3

Age (days)	E	I	II	III	IV	P_1	P_2	A	Totals
0	198								198
1	186	12							198
2		142	3						145
3		135	3						138
4		78	54						132
5		3	126	2					131
6			98	10					108
7			11	95	2				108
8			9	65	15				89
9			4	17	51				72
10				5	64	3			72
11				2	51	5			58
12					2	44	3		49
13						5	43	1	49
14							31	5	36
15							3	31	34
16							1	24	25
17								23	23
18								19	19
19								19	19
20								15	15
21								11	11
22								10	10
23								8	8
24								6	6
25								5	5
26								4	4
27								2	2
28								1	1
29								0	0

Table 18: Daily records for Life-tables studies of immature stages of *Culex quinquefasciatus* surviving in the laboratory.

Cage 4

Age (days)	E	I	II	III	IV	P_1	P_2	A	Totals
0	203								203
1	172	31							203
2		155	2						157
3		155	2						157
4		136	4						140
5		4	128	3					135
6			108	12					120
7			13	94	5				112
8			8	72	16				96
9			7	14	62				83
10				4	75	4			83
11					57	7			65
12					3	56	6		65
13						4	47	3	54
14							45	7	52
15							6	32	38
16							2	27	29
17								25	25
18								20	20
19								18	18
20								12	12
21								12	12
22								10	10
23								7	7
24								5	5
25								4	4
26								3	3
27								2	2
28								2	2
29								0	0

3.2 Weekly Samplings

Table 19: Estimated population size of immature stages of *C. thalassius*, 6th August 1980 through 29th July 1981 (based on 10-dip samples on each sample day)

Locality: Malam

Week	Date	*Culex thalassius larvae*	Pupae	Week	Date	*Culex thalassius larvae*	Pupae
1	6-8-80	14		27	4-2-81	43	
2	13-8-80	205		28	11-2-81	36	
3	20-8-80	451		29	18-2-81	33	
4	27-8-80	503		30	25-2-81	24	
5	3-9-80	496		31	4-3-81	34	
6	10-9-80	505		32	11-3-81	8	
7	17-9-80	572		33	18-3-81	10	15
8	24-9-80	638		34	25-3-81	8	5
9	1-10-80	641		35	1-4-81	14	6
10	8-10-80	668		36	8-4-81	84	712
11	15-10-80	589		37	15-4-81	38	14
12	22-10-80	735		38	22-4-81	5	6
13	29-10-80	1474		39	29-4-81	6	4
14	5-11-80	895		40	6-5-81	0	0
15	12-11-80	2010		41	13-5-81	0	0
16	19-11-80	2270		42	20-5-81	3543	62
17	26-11-80	620		43	27-5-81	14110	177
18	3-12-80	754		44	3-6-81	1030	107
19	10-12-80	1178		45	10-6-81	10186	1810
20	17-12-80	1277		46	17-6-81	1970	4
21	24-12-80	1248		47	24-7-81	5	0
22	31-12-80	407		48	1-7-81	3	0
23	7-1- 81	975		49	8-7-81	0	0
24	14-1- 81	516		50	15-7-81	0	0
25	21-1- 81	46		51	22-7-81	0	0
26	28-1- 81	35		52	29-7-81	0	0

Table 20: Estimated population size of immature stages of *C. quinquefasciatus & C. tigripes*, 10 September 1980 through 2nd September 1981 (based on 20-dip samples on each sample day)

Locality: NIMA

Week	Date	*Culex tigri-pes*	*Culex fati-gans*	Total pupae	Week	Date	*Culex tigri-pes*	*Culex fati-gans*	Total pupae
1	10.9.80	4	498	19	34	29.4.81	0	5	2
2	17.9.80	8	115	42	35	6.5.81	0	0	0
3	24.9.80	10	282	37	36	13.5.81	0	0	0
4	1.10.80	20	261	32	37	20.5.81	0	0	0
5	8.10.80	4	290	31	38	27.5.81	0	0	0
6	15.10.80	3	447	18	39	3.6.81	0	22	3
7	22.10.80	0	32	5	40	10.6.81	0	0	0
8	29.10.80	8	342	38	41	17.6.81	0	2	2
9	5.11.80	8	402	23	42	24.6.81	0	0	0
10	12.11.80	15	510	25	43	1.7.81	0	5	9
11	19.11.80	25	182	58	44	8.7.81	1	0	0
12	26.11.80	28	314	30	45	15.7.81	0	38	0
13	3.12.80	32	94	6	46	22.7.81	0	5	1
14	10.12.80	38	89	12	47	29.7.81	37	698	217
15	17.12.80	50	840	16	48	5.8.81	0	26	5
16	24.12.80	63	1118	14	49	12.8.81	65	1353	108
17	31.12.80	52	2036	122	50	19.8.81	159	2887	85
18	7.1. 81	41	1221	17	51	26.8.81	96	840	325
19	14.1. 81	210	447	54	52	52.9.81	58	587	284
20	21.1. 81	68	210	29					
21	28.1. 81	857	1447	164					
22	4.2. 81	648	2166	85					
23	11.2. 81	762	1897	272					
24	18.2. 81	0	15	4					
25	25.2. 81	13	278	3					
26	4.3. 81	11	114	15					
27	11.3. 81	11	107	40					
28	18.3. 81	3	29	24					
29	25.3. 81	0	8	3					
30	1.4. 81	0	2	0					
31	8.4. 81	0	0	0					
32	15.4. 81	0	9	6					
33	22.4. 81	2	4	4					

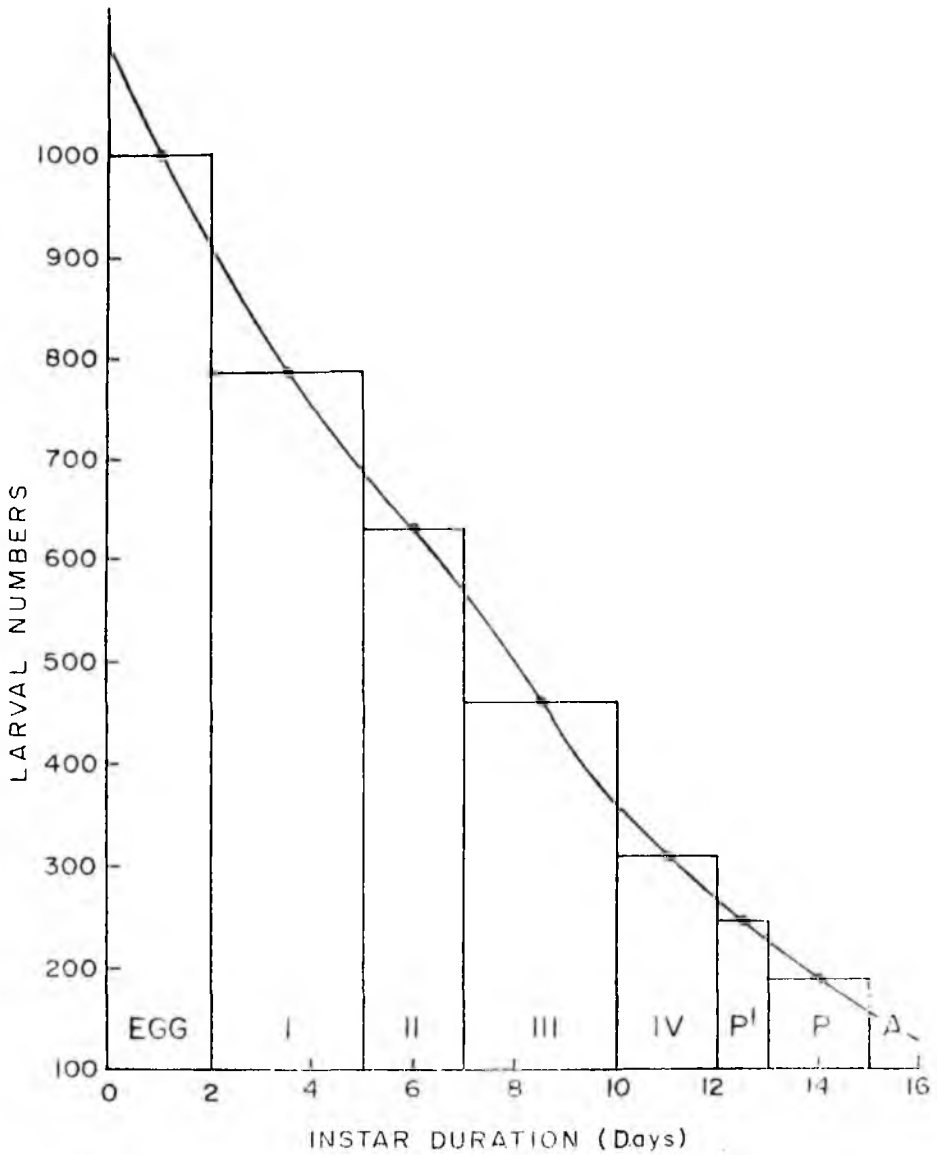

Fig. 3 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX QUINQUEFASCIATUS IN THE LABORATORY.
(REFER TO TABLE 1A)

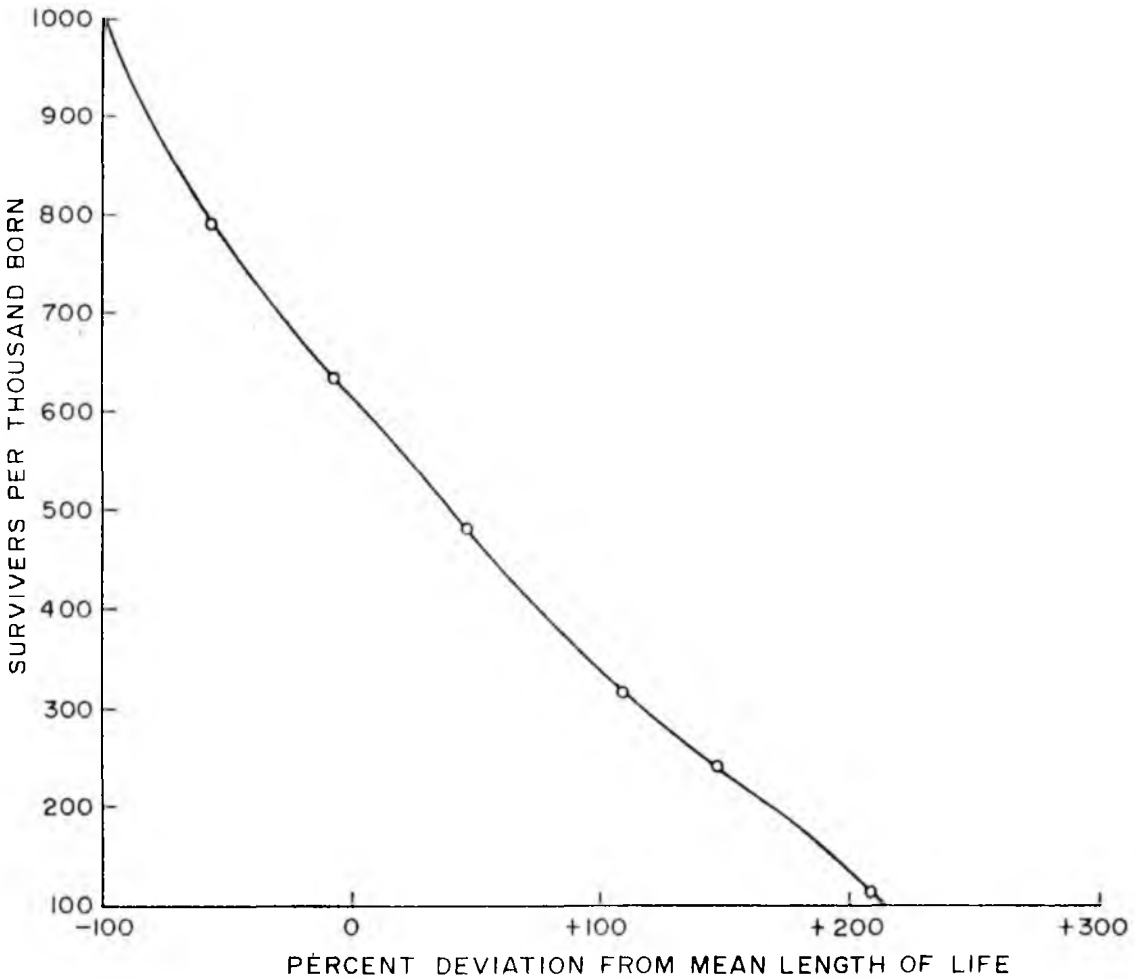

Fig. 4 SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX QUINQUEFASCIATUS IN THE LABORATORY.
(REFER TO TABLE 12)

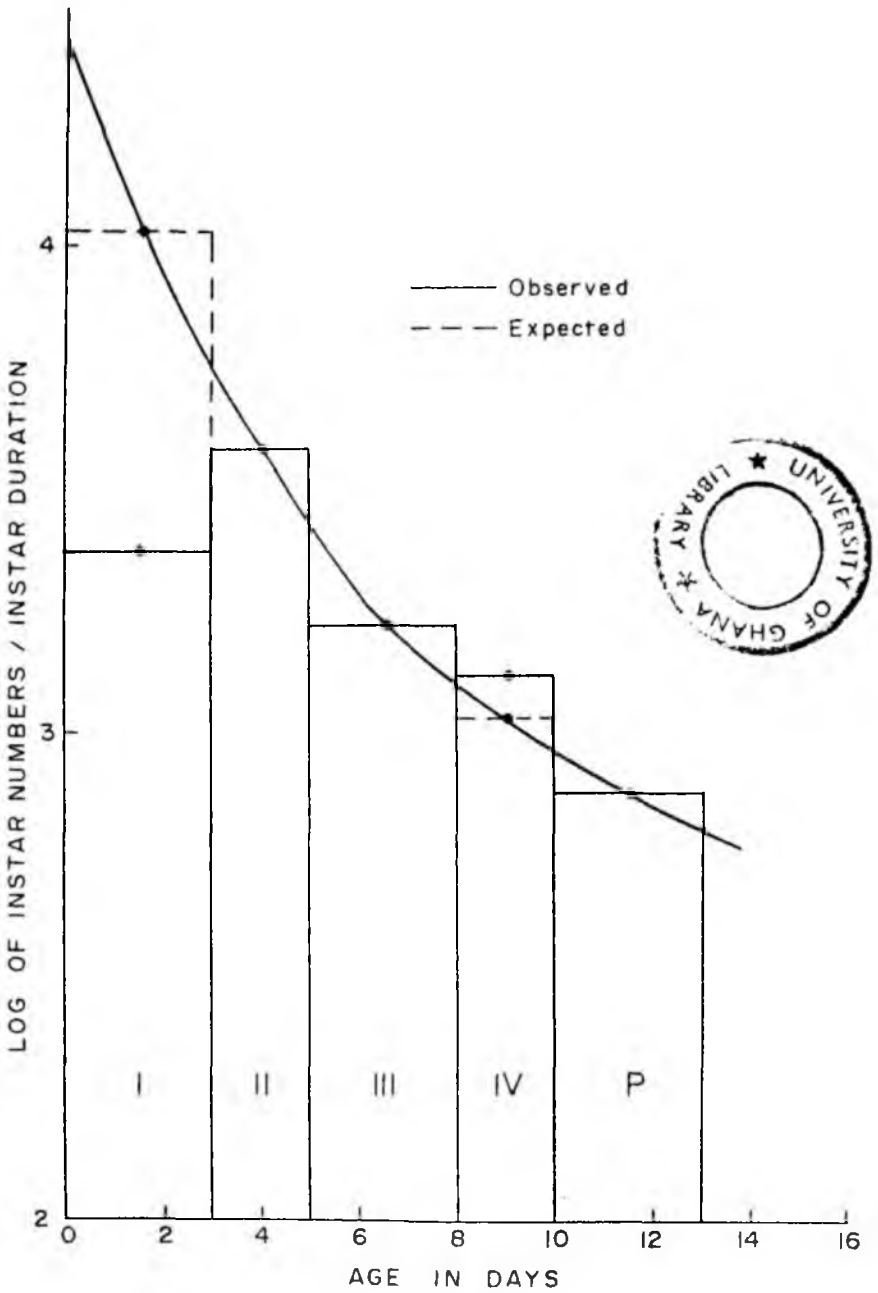

Fig. 5 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX QUINQUEFASCIATUS AT NIMA
A year's observation. (Refer to Table 8)

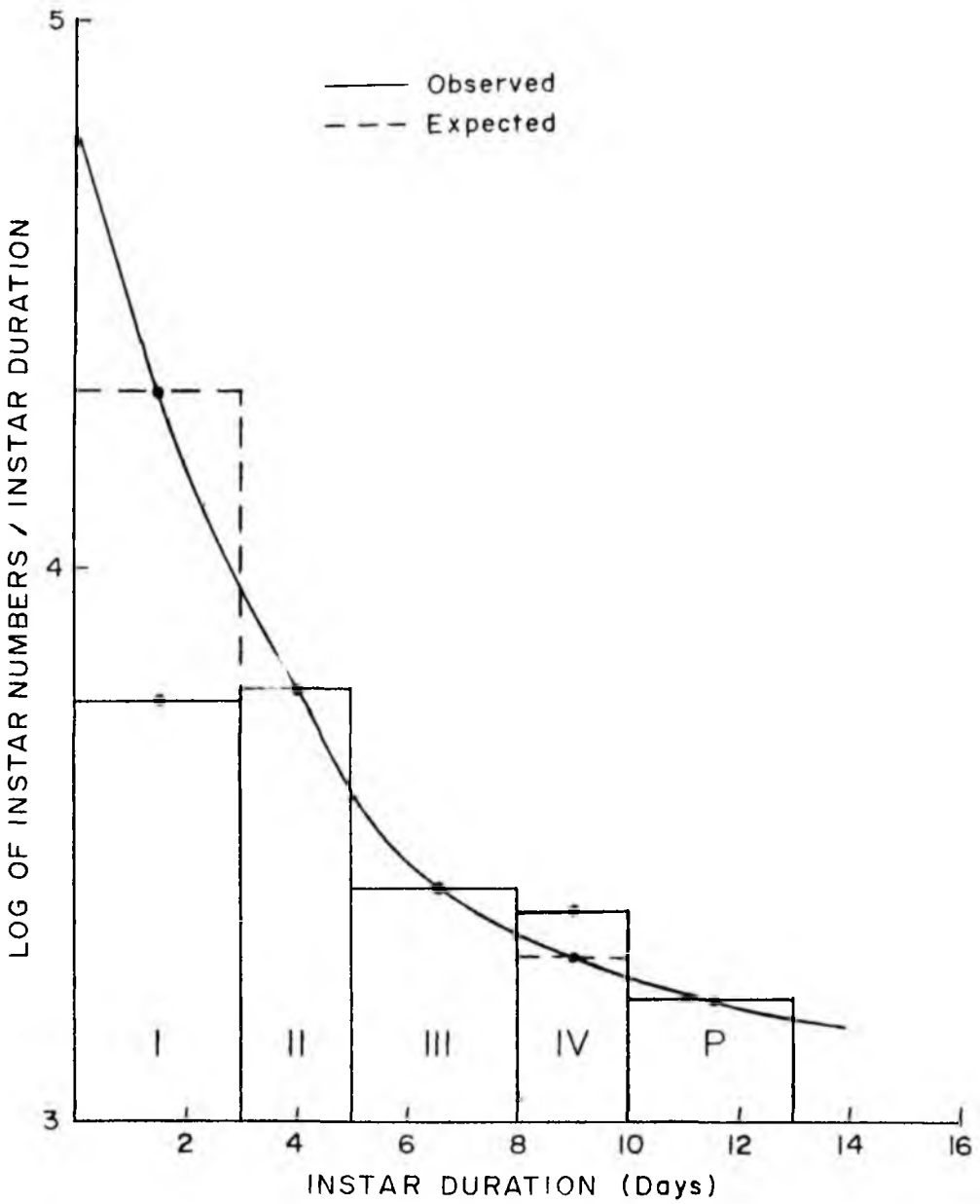

Fig. 6 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX QUINQUEFASCIATUS (Table 9), AT NIMA
Values for the 2nd to the 6th day of collection

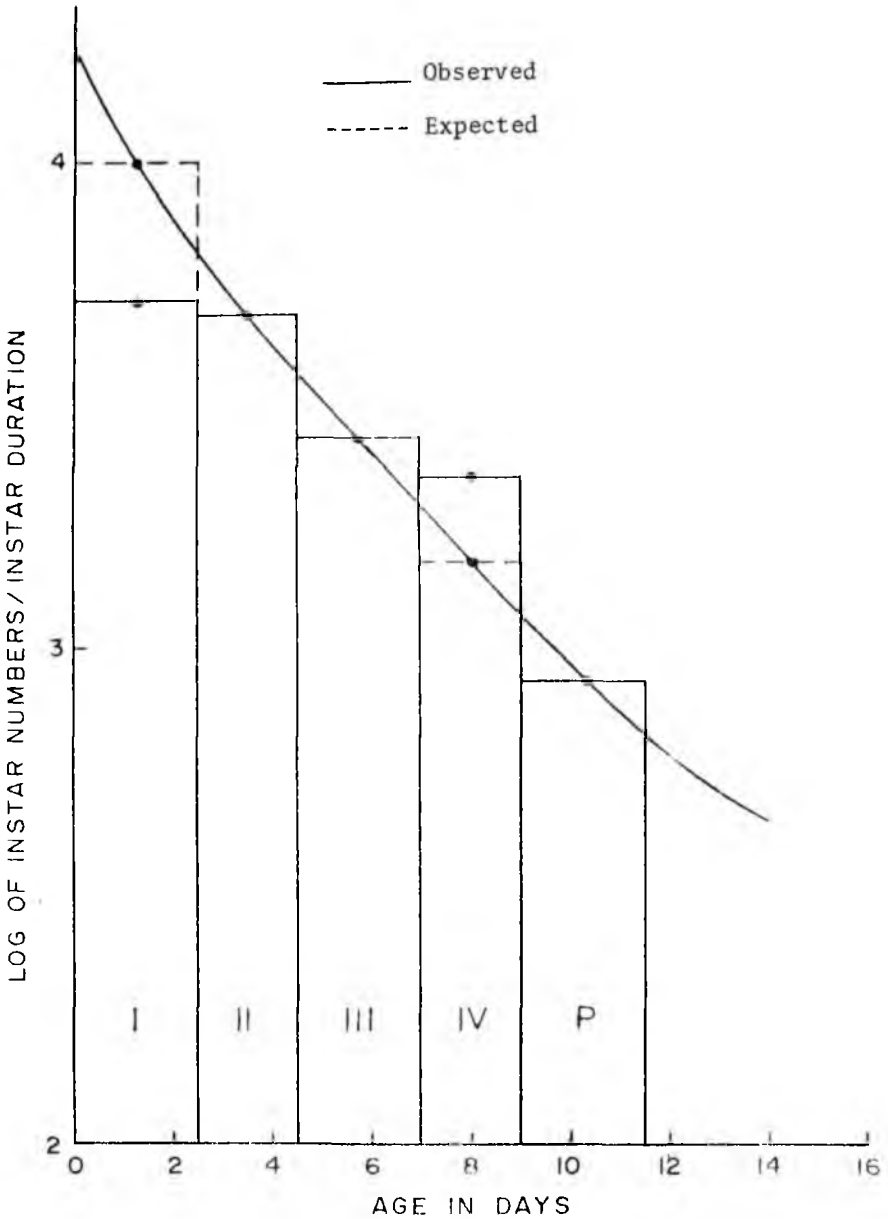

Fig. 7 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX THALASSIUS (Table 8) AT MALAM A years' observation.

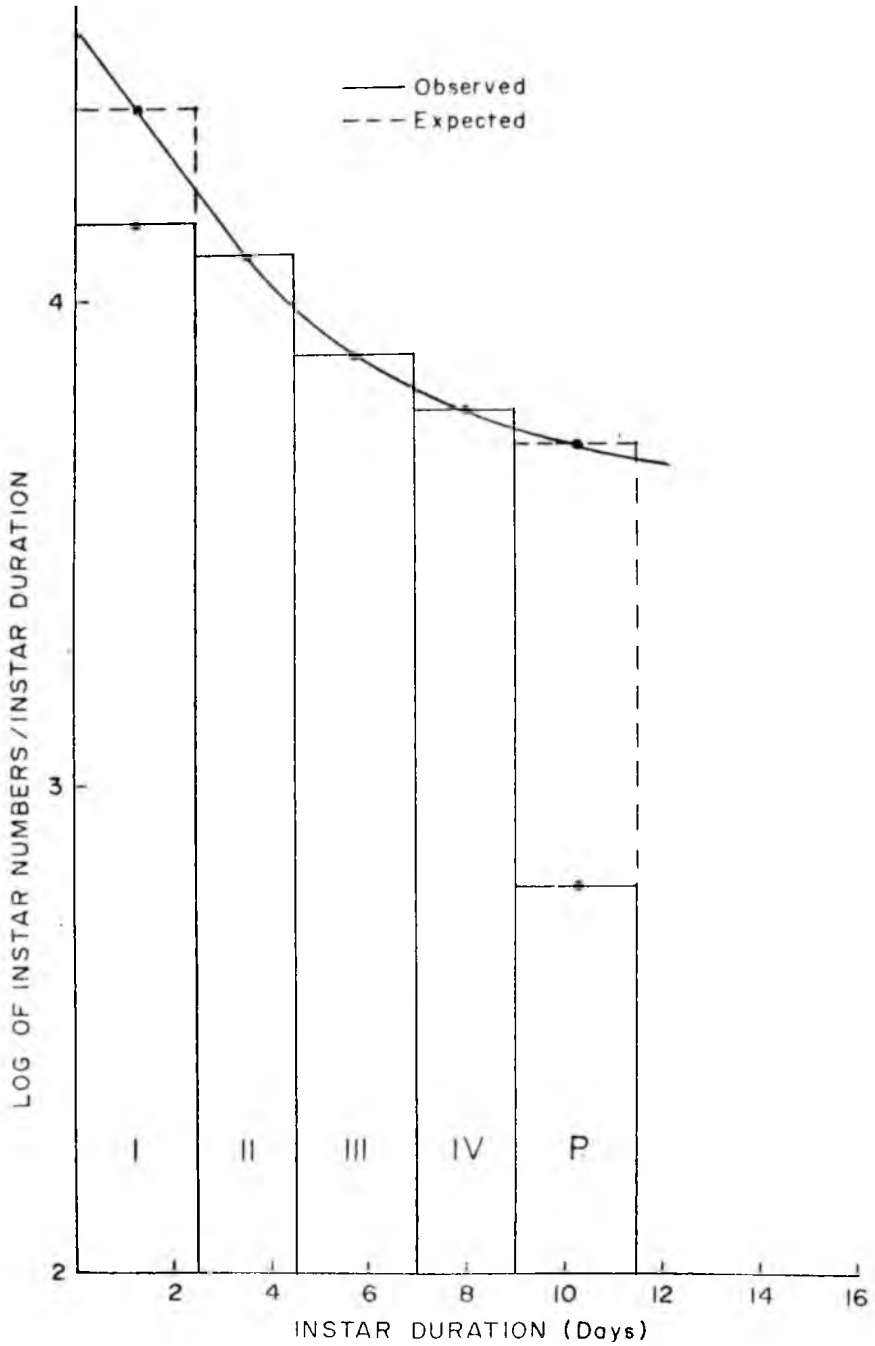

Fig. 8 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX THALASSIUS (Table 6) AT MALAM
Values for the 5th to the 15th day of collection.

3.21: Light traps:

Table 21: Effects of Light Trap Experiment on larvae (L) and pupae (P) of *Culex thalassius* compared in the laboratory.

Expt.	No. used			No. and % of larvae and pupae in light			% of original mosquitoes trapped.		
	L	P	Total	L	P	Total	L	P	Total
1	100	100	200	180 (94%)	10 (6%)	190	90	5.0	95.0
2	100	100	200	156 (83%)	32 (17%)	188	78	16.0	94.0
3	100	100	200	168 (87%)	25 (13%)	193	84	12.5	96.5
4	100	100	200	174 (94%)	11 (6%)	185	87	5.5	92.5
5	100	100	200	169 (88%)	23 (12%)	192	84.5	11.5	96.0

% of original Larvae trapped = 85%
% of original Pupae trapped = 10%
Total % of original mosquitoes trapped = 95%
Ratio of larvae: pupae in light trap = 89:11.

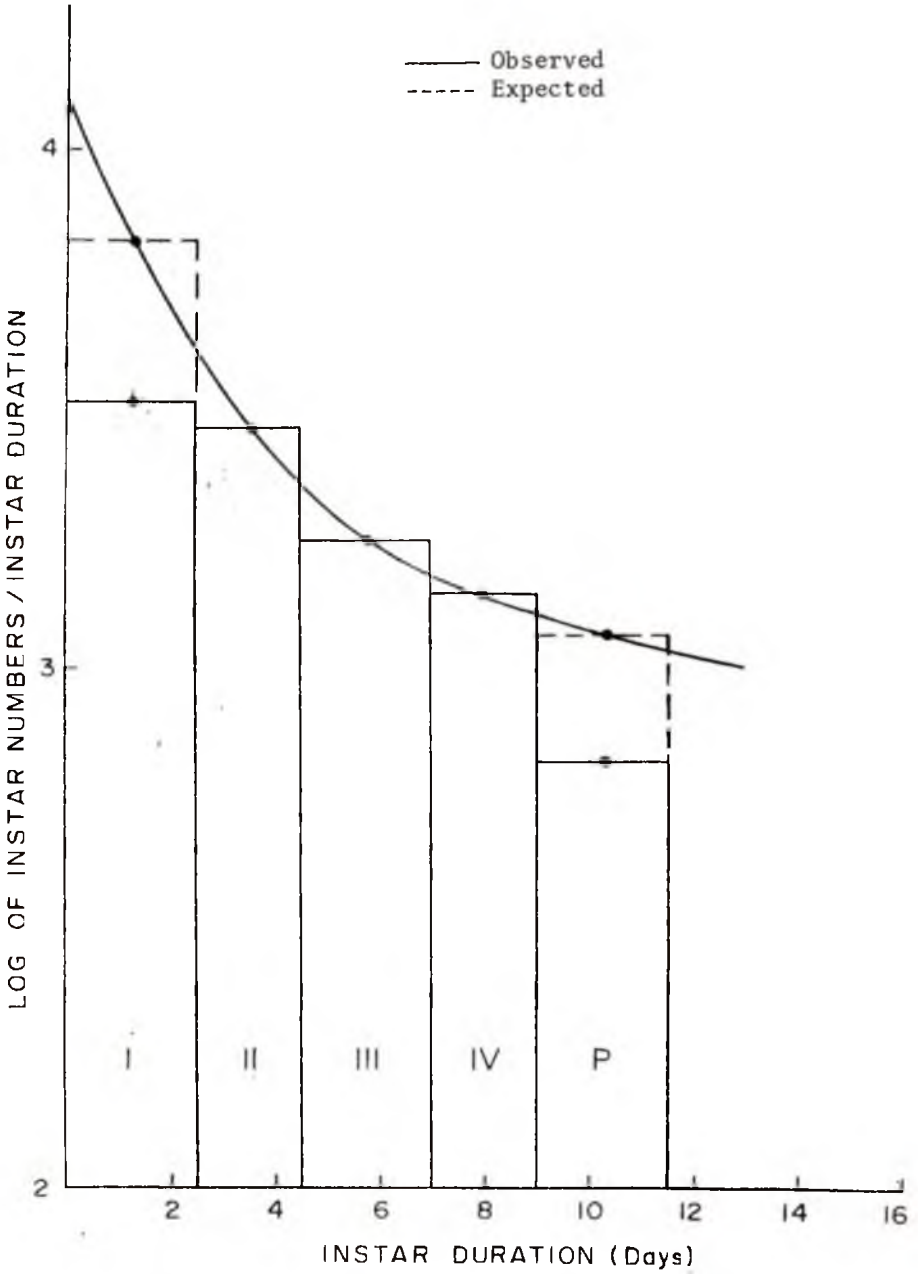

Fig. 9 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX THALASSIUS (Table 4) Values from the 7th to 11th day of collection, AT CHORKOR LAGOON

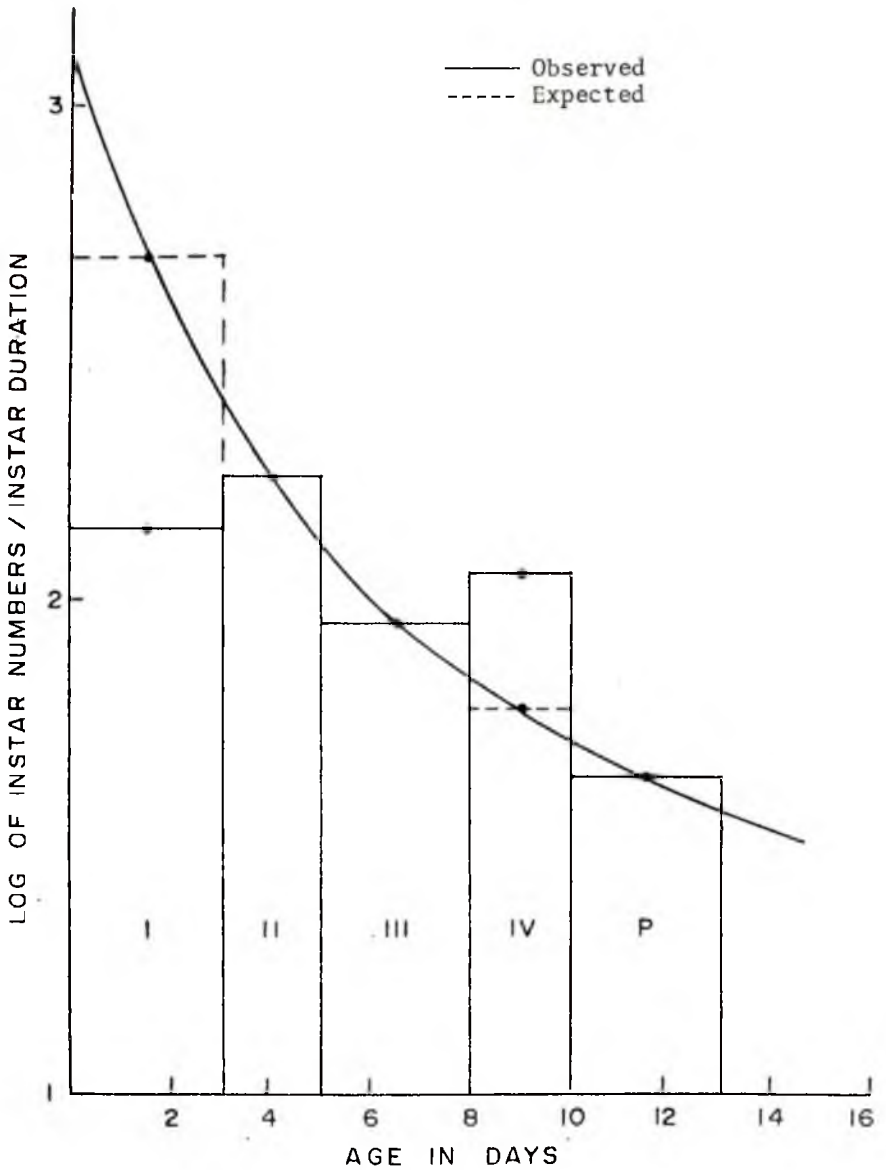

Fig. 10 AGE DISTRIBUTION AND SURVIVORSHIP CURVE OF IMMATURE STAGES OF CULEX DUTTONI, JUNE 1981. (Table 3) AT LEGON

3.22 Sticky traps

Table 22: Effects of Sticky Trap on larvae (l) and pupae(P) of *Culex thalassius* compared in the laboratory.

	No. used			No. and % of larvae and pupae in sticky trap			% trapped		
Expt.	L	P	Total	L	P	Total	L	P	Total
1	50	50	100	32 (39%)	50 (61%)	82	64	100	82
2	50	50	100	28 (36%)	50 (64%)	78	56	100	78
3	50	50	100	31 (38%)	50 (62%)	81	62	100	81
4	50	50	100	30 (38%)	50 (62%)	80	60	100	80
5	50	50	100	28 (36%)	50 (64%)	78	56	100	78

% of original Larvae trapped = 60%
% of original Pupae trapped = 100%
Total % of original mosquito trapped = 80%
Ratio of larvae and pupae in sticky trap = 37:63.

TABLE 23: SAMPLE OF CULEX THALASSIUS POPULATION : SIMULTANEOUS SETS OF PAIRED CATCHES ON LIGHT AND STICKY TRAPS FOR 10 CONTINUOUS DAYS INDICATING LARVAE (l) PUPAE (P) TOTAL CATCH (C) PERCENTAGE CAUGHT (% in brackets) AND DIFFERENCE (d) BETWEEN CATCHES WITH THE TWO TRAPS OAT DIFFERENT SITES (A,B,C,D,E) AT CHORKOR LAGOON, 10TH AUGUST 1981 THROUGH 19TH AUGUST 1981.

TIME (DAY)		(10.8.81) 1				(11.8.81) 2				(12.8.81) 3				(13.8.81) 4				(14.8.81) 5			
SITE	TRAP	l	p	c	d	l	p	c	d	l	p	c	d	l	p	c	d	l	p	c	d
A	Light	1134	386	1520		1486	548	2034		1058	287	1345		915	205	1120		615	335	950	
	(%)	(75)	(25)		560	(73)	(27)		1384	(79)	(21)		617	(82)	(18)		515	(65)	(35)		37
	Sticky	225	735	960		235	415	650		113	615	728		290	315	605		493	420	913	
	(%)	(23)	(77)			(36)	(64)			(15)	(85)			(48)	(52)			(54)	(46)		
B	Light	1015	201	1216		2800	320	3120		2520	648	3168		820	195	2015		118	802	1920	
	(%)	(83)	(17)		166	(90)	(10)		1170	(80)	(20)		992	(90)	(10)		935	(58)	(42)		155
	Sticky	180	870	1050		825	1125	1950		441	1735	2176		515	1435	2950		843	1232	2075	
	(%)	(17)	(83)			(42)	(58)			(20)	(80)			(51)	(49)			(41)	(59)		
C	Light	1053	527	1590		[illegible]	370	875		750	230	980		1203	372	1575		1204	136	1340	
	(%)	(67)	(33)		1127	(58)	(42)		225	(77)	(23)		477	(77)	(23)		758	(90)	(10)		185
	Sticky	137	316	453		156	494	650		185	318	503		414	403	817		807	718	1525	
	(%)	(30)	(70)			(24)	(76)			(37)	(63)			(51)	(49)			(53)	(47)		
D	Light	2164	739	2903		2215	860	3075		985	275	1260		1315	400	1715		1125	403	1528	
	(%)	(75)	(25)		1053	(72)	(28)		1545	(78)	(22)		125	(77)	(23)		498	(74)	(26)		520
	Sticky	769	1081	1856		282	708	1530		705	680	1385		602	615	1217		593	415	1008	
	(%)	(41)	(59)			(18)	(82)			(51)	(49)			(49)	(51)			(59)	(41)		
E	Light	3218	1342	4560		1405	270	1675		2512	891	3403		3117	899	4016		2125	1093	3218	
	(%)	(70)	(30)		2364	(84)	(16)		290	(74)	(26)		1361	(78)	(22)		841	(66)	(34)		300
	Sticky	688	1508	2196		747	1218	1965		922	1120	2042		1755	1420	3175		1598	1320	2918	
	(%)	(31)	(69)			(38)	(62)			(45)	(55)			(55)	(45)			(55)	(45)		

(2) Table 23 (cont'd) SAMPLE OF CULEX THALASSIUS POPULATION: SIMULTANEOUS SETS OF PAIRED CATCHES ON LIGHT AND STICKY TRAPS FOR 10 CONTINUOUS DAYS INDICATING LARVAE (l) PUPAE (P) TOTAL CATCH (C), PERCENTAGE CAUGHT (% in brackets) AND DIFFERENCE (d) BETWEEN CATCHES WITH THE TWO TRAPS AT DIFFERENT SITES (A,B,C,D,E). AT CHORKOR LAGOON, 10th AUGUST 1981 THROUGH 19th AUGUST 1981.

TIME (DAY)		(15.8.81) 6				(16.8.81) 7				(17.8.81) 8				(18.8.81) 9				(19.8.81) 10			
SITE	TRAP	l	p	c	d	l	p	c	d	l	p	c	d	l	p	c	d	l	p	c	d
A	Light	705	114	819		619	89	708		412	108	520		380	36	416		719	86	805	
	(%)	(87)	(13)		4	(87)	(13)		307	(79)	(21)		1292	(91)	(9)		100	(89)	(11)		495
	Sticky	412	403	815		226	789	1015		754	1058	1812		197	319	516		90	220	310	
	(%)	(51)	(49)			(22)	(78)			42)	(58)			(38)	(62)			(29)	(71)		
B	Light	1258	243	1501		703	215	918		615	198	813		625	80	705		505	110	615	
	(%)	(84)	(16)		109	(77)	(23)		9	76)	(24)		212	(89)	(11)		193	(82)	(18)		90
	Sticky	777	615	1392		404	523	927		155	870	1025		381	517	898		193	512	705	
	(%)	(56)	(44)			(44)	(56)			15)	(85)			(42)	(58)			(27)	(73)		
C	Light	750	165			432	163	595		530	275	805		418	191	609		529	321	850	
	(%)	(82)	(18)	915	101	(73)	(27)		77	66)	(34)		89	(68)	(32)		206	(62)	(38)		544
	Sticky	702	314	1016		198	320	518		303	413	716		265	550	815		11	295	306	
	(%)	(69)	(31)			(38)	(62)			(42)	(58)			(33)	(67)			(3)	(97)		
D	Light	1216	127	1345		1015	113	1128		716	197	913		826	189	1015		1581	124	1705	
	(%)	(91)	(9)		429	(90)	(10)		212	(78)	(22)		337	(81)	(19)		197	(92)	(8)		787
	Sticky	410	506	916		490	850	1340		570	680	1250		323	495	818		388	530	918	
	(%)	(45)	(55)			(37)	(63)			(46)	(54)			(39)	(61)			(42)	(58)		
E	Light	2425	600	3025		2517	291	2808		2089	406	2495		320	495	1815		1132	355	1487	
	(%)	(80)	(20)		1499	(90)	(10)		1836	(84)	(16)		1154	(73)	(27)		937	(76)	(24)		837
	Sticky	507	1019	1526		442	530	972		428	913	1341		369	509	878		164	486	650	
	(%)	(33)	(67)		-	(45)	(55)			(32)	(68)			(42)	(58)			(25)	(75)		

KEY: l = larvae
p = pupae
c = catch
d = difference between catches.

% Larvae and Pupae trapped

Ratio of Larvae: Pupae in light trap = 78:22
Ratio of Larvae: Pupae in Sticky trap = 38:62

TABLE 24 SAMPLE OF CULEX THALASSIUS POPULATION: SIMULTANEOUS SETS OF PAIRED CATCHES ON LIGHT AND STICKY TRAPS FOR TEN CONTINUOUS DAYS INDICATING TOTAL CATCHES (C) AND DIFFERENCE (D) BETWEEN CATCHES OF THE TWO TRAPS AT CHORKOR LAGOON. 10th AUGUST 1981 THROUGH 19th AUG.1981

SP' NO	1		2		3		4		5		6		7		8		9		10	
T.(DAY)	1 (10.8.81)		2 (11.8.81)		3 (12.8.81)		4 (13.8.81)		5 (14.8.81)		6 (15.8.81)		7 (16.8.81)		8 (17.8.81)		9 (18.8.81)		10 (19.8.81)	
ST*TRAP	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D	C	D
LIGHT	1520		2034		1345		1120		950		819		708		520		416		865	
A		560		- 1384		617		515		37		4		307		1292		103		495
STICKY	960		650		728		[illegible]		913		815		1015		1812		519		[illegible]	
LIGHT	1216		3120		3168		2015		1920		1501		918		813		705		[illegible]	
B		166		1170		992		935		155		109		9		212		153		90
STICKY	1050		1950		2176		1950		2075		1342		927		[illegible]		858		[illegible]	
LIGHT	1580		875		980		1575		1340		915		595		805		609		650	
C		1127		225		477		758		485		101		77		89		206		[illegible]
STICKY	453		650		503		817		1525		1016		518		716		815		306	
LIGHT	2903		3075		3260		1715		1518		1345		1128		913		1015		1705	
D		1053		1545		125		498		[illegible]		429		212		127		[illegible]		[illegible]
STICKY	1856		1530		1385		1217		1008		916		1340		[illegible]		816		[illegible]	
LIGHT	4560		1675		3403		4616		3218		[illegible]		2926		[illegible]		[illegible]		1487	
E		2364		296		1361		641		360		1493		1636		1164		937		[illegible]

TABLE 25 CALCULATION OF MEAN POPULATION DENSITY AND VARIANCE OF CULEX THALASSIUS POPULATION, BASED ON DIFFERENCES BETWEEN CATCHES ON LIGHT AND STICKY TRAPS FOR TEN CONTINUOUS DAYS AT CHORKOR LAGOON (AS INDICATED 1 TO 10) 10th AUGUST 1981 THROUGH 19th AUG.1981 (Refer to Table 24).

NO	1	2	3	4	5	6	7	8	9	10	11	12
1.	560.00	1384.00	617.00	515.00	37.00	4.00	307.00	1292.00	100.00	495.00		
2.	160.00	1170.00	992.00	935.00	155.00	109.00	9.00	212.00	193.00	90.00		
3.	1127.00	225.00	477.00	758.00	165.00	101.00	77.00	89.00	206.00	544.00		
4.	1053.00	1545.00	125.00	498.00	520.00	429.00	212.00	337.00	197.00	787.00		
5.	2364.00	290.00	1361.00	841.00	300.00	1499.00	1836.00	1154.00	937.00	837.00		

STATISTICS FOR THE PERIOD (5) TIMES.

TOTALS	5270.000 2142.000	4614.000 2441.000	3572.000 3084.000	3547.000 [illegible]	1197.000 2753.[illegible]
M E A N	1054.000 428.400	922.800 488.200	714.400 616.800	[illegible] [illegible]	239.400 [illegible]
LOG-MEAN	6.960 6.060	6.827 6.190	6.571 6.424	[illegible] [illegible]	[illegible] [illegible]
SUM(D-SQ)	8308591.013 2453140.505	5806107.011 3516099.505	[illegible] [illegible]	2069299.506 [illegible]	[illegible] [illegible]
SUM-SQ.	27772904.054 4588165.011	21289000.04[illegible] 5958482.013	[illegible] [illegible]	[illegible] [illegible]	1432809.252 [illegible]
STD-DEVT.	742.[illegible] 554.[illegible]	556.472 681.821	[illegible] [illegible]	[illegible] [illegible]	[illegible] 265.780
VARIANCE.	550802.126 307101.563	309661.563 464880.625	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
SD**2	137700.531 76775.390	77415.390 116220.156	[illegible] [illegible]	[illegible] 23656.269	[illegible] 17059.875
SD/2	68850.265 38387.695	38707.695 58110.07[illegible]	[illegible] [illegible]	3824.451 [illegible]	[illegible] [illegible]
LOG SD/2.	11.139 10.555	10.563 10.970	[illegible] 10.361	[illegible] [illegible]	[illegible] [illegible]

3.3 Physico-chemical characteristics of soil and water

Determination of Salinity:

Remarks: 1 ml. of the weak silver nitrate. Solution to reach the end point of 4 ml. of water tested indicates 2.5g. of chloride per litre.

Results:

(a) For strong $AgNO^3$ (Water from Malam)

	i	ii	iii	iv	v
Final	8.0	7.8	7.9	8.0	8.2
Initial	4.0	4.0	4.0	4.0	4.0
Volume	4.0	3.8	3.9	4.0	4.2

Average volume = 3.98mls.

(b) For weak $AgNO_3$ (Water from Nima)

	i	ii	iii	iv	v
Final	5.1	5.1	5.0	5.1	5.1
Initial	4.0	4.0	4.0	4.0	4.0
Volume	1.1	1.1	1.0	1.1	1.1

Average Volume = 1.10 mls.

Calculation of Chloride content:

This is obtained by multiplying by 0.5 or 2.5 (as the case may be) the number of millilitres of Silver nitrate required to reach the end point with a 4 ml water sample.

(a) For strong salt (water from Malam)

Average volume of water used = 3.98 mls.

Chloride content = 2.5 x 3.98 = 9.95g CI^-/litre.

(b) For Weak salt (water from Nima)

Average volume of water used = 1.1 mls.

Chloride content = 0.5 x 1.1 = 0.55gCI^-/litre.

For strong $AgNO_3$ (Dried soil from Malam)

	i	ii	iii	iv	v
Final	5.3	5.2	5.1	5.2	5.2
Initial	4.0	4.0	4.0	4.0	4.0
Volume	1.3	1.2	1.1	1.2	1.2

Average volume = 1.20 mls.

For Weak $AgNO_3$ (Dried soil from Nima)

	i	ii	iii	iv	v
Final	5.0	5.0	5.1	5.0	5.1
Initial	4.0	4.0	4.0	4.0	4.0
Volume	1.0	1.0	1.1	1.0	1.1

Average volume = 1.04 mls.

Calculation of Chloride content

(a) For strong salt (soil from Malam)

Average volume of water used = 1.20 mls.

Chloride (Cl^-) content = 1.20 x 2.50 = 3.0g Cl^-/l.

Treatment of Results: Determination of Oxygen content.

If 200cc. of sample is titrated, the number of cc of the sodium thiosulphate solution used is numerically equal to the dissolved oxygen content in parts per million and no additional calculation is necessary. This value multiplied 0.698 yields O_2 dissolved in c.c. per litre.

Results:

Titration of Water from Malam.

	i	ii	iii
Final	10.0	10.5	10.5
Initial	0.0	0.5	0.5
Volume	10.0	10.0	10.0

Average = 10.0 mls.

Titration of water from Nima

	i	ii	iii
Final	1.0	2.0	3.5
Initial	0.0	1.0	2.5
Volume	1.0	1.0	1.0

Average = 1.0 mls.

1. The concentration of Oxygen in Malam = 10 ppm. or 6.98 cc. per litre.
2. The concentration of Oxygen at Nima = 1 ppm or 0.698 cc. per litre.

Table 26: Physico-chemical analysis of water and soil at Nima and Malam compared.

PHYSICO-CHEMICAL ANALYSIS

	WATER		SOIL	
	Malam	Nima	Malam	Nima
5-2-81 pH	6.9	8.2	5.9(5.7)	8.0(7.2)
Na(i) ppm	15,000	370.0	700	35
(ii) meq/l	652.10	16.08	-	-
(iii) meq/100gSoil	-	-	30.43	1.52
O_2 ppm	10	1	-	-
Cl^- g/l	9.95	0.55	3.0	0.52
%C	-	-	0.433	0.216
Organic matter *	-	-	0.745	0.372
18-5-81 pH	3.2	7.9	5.9	7.2
Na(i) ppm	21,500	250.0	3,100	10.5
(ii) meq/l	847.82	10.87	-	-
(iii) meq/100gSoil	-	-	134.74	0.457
02 ppm	9.50	0.8	-	-
Cl^- g/l	9.88	0.55	2.88	0.52
%C	-	-	0.35	0.19
Organic matter *	-	-	0.6035	0.3276
20-6-81 pH	3.8	7.8	4.1	7.1
Na(i) ppm	24,000	350.0	3,300	10.25
(ii) meq/l	1043.48	14.78	-	-
(iii) meq/100gSoil	-	-	143.47	0.446
02 ppm	10.5	1.2	-	-
Cl^- g/l	9.75	0.55	2.75	0.52
%C	-	-	0.480	0.160
Organic matter *	-	-	0.8275	0.2758

* Average Organic matter of soil was 0·7253 for Malam and 0·3251 for Nima

Table 27: Physico-chemical analysis of the water and soil at Nima and Malam compared.

ANALYSIS ON WATER SAMPLES:

5-2-81.

Location	pH	Na		O_2	Cl^-
		ppm	meq/l	ppm	gm/l
Malam	6.9	15,000	652.10	10	9.95
Nima	8.4	370	16.08	1	0.55

ANALYSIS ON SOIL SAMPLE 5-2-81

Location	pH in H_2O 1:2	in 0.01m CaCl 1:2	%C	Organic matter	ppm	Na. in eq per 100g Soil	Cl^- gm/l
Malam	5.9	5.7	0.432	0.745	700	30.43	3.0
Nima	7.73	7.2	0.216	0.372	35	1.52	0.52

18-5-81

ANALYSIS ON WATER SAMPLE

Location	pH	Na		O_2	Cl^-
		ppm	meq/l	ppm	gm/l
Malam	3.2	21,500	847.82	9.5	9.88
Nima	7.9	250.0	1043.48	0.8	0.55

3.4. Insecticide Susceptibility tests.

Table 28 TEST FOR DDT INSECTICIDE RESISTANCE IN 4th INSTAR LARVAE OF CULEX QUINQUEFASCIATUS COLLECTED AT NIMA.

Tests	Replicate 1			Replicate 2			Replicate 3			Replicate 4			Totals (for comparable tests only)			
Date of test	25·2·81			27·2·81			2·3·81			4·3·81						
Temperature during test (°C)	27 °C			27 °C			27 °C			27 °C						
Insecticide concentration (ppm)	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	Probit
0·002	3	3	8·3	2 3	5	16·6	4	4	8·7	2	4	8·7	3 13	16	10·6	3·75
0·004	1 9	10	37·5	2 7	9	33·6	2 6	8	21·6	13	7	21·7	7 27	34	29·8	4·46
0·02	12	12	45·8	13	13	50·0	1 12	13	47·8	25	12	43·5	2 48	50	46·8	4·92
0·10	15	15	58·3	15	15	58·3	14	14	52·2	1 11	13	47·8	57	57	54·2	5·11
0·50	18	18	70·8	19	19	75·3	17	17	65·2	13	18	69·6	72	72	70·2	5·53
1·0	1 21	22	87·5	23	23	91·7	1 20	21	82·6	18	24	95·7	4 86	90	89·4	6·25
2·5	24	24	95·8	25	25	100	24	24	95·6	22	25	100	96	98	97·9	7·05
Control	1	1	0	1	1	0	2	2	0	2	2	0	6	6	0	0

(Abbreviations "M" – moribund; "D" – dead)
Correct by applying Abbott's formula* if control mortality is between 5% and 20% (see instructions).

*ABBOTT'S FORMULA: Corrected mortality % = $\frac{\text{Observed mortality \% – Control mortality \%}}{\text{100 – Control mortality \%}} \times 100$

Table 29 TEST FOR DIELDRIN INSECTICIDE RESISTANCE IN 4th INSTAR LARVAE OF CULEX QUINQUEFASCIATUS COLLECTED AT NIMA.

Tests	Replicate 1			Replicate 2			Replicate 3			Replicate 4			Totals (for comparable tests only)			
Date of test	25·2·81			27·2·81			2·3·81			4·3·81						
Temperature during test (°C)	27°C			27°C			27°C			27°C						
Insecticide concentration (ppm)	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	Probit
0·002	2 3	5	16·7	2 6	8	26·1	2 8	10	34·8	7	7	18·2	6 24	30	23·9	4·29
0·004	2 6	8	29·2	2 7	9	30·4	2 9	11	39·1	11	11	36·4	3 33	36	33·7	4·57
0·02	14	14	54·2	16	16	60·9	14	14	52·2	15	15	54·5	59	59	55·4	5·13
0·10	2 15	17	66·7	2 17	19	73·9	17	17	65·2	18	18	68·2	4 67	71	68·5	5·48
0·50	19	19	75·0	1 20	21	82·6	1 20	21	82·6	1 19	20	77·3	3 78	81	79·4	5·82
1·0	21	21	83·3	22	22	86·9	1 21	22	86·9	21	21	81·8	1 85	86	84·8	6·03
2·5	25	25	100	24	24	95·7	25	25	100	25	25	100	99	99	98·9	7·23
Control	1	1	0	2	2	0	2	2	0	1 2	3	0	1 7	8	0	0

(Abbreviations: "M" – moribund; "D" – dead)
Correct by applying Abbott's formula* if control mortality is between 5% and 20% (see instructions).
*ABBOTT'S FORMULA: Corrected mortality % = $\frac{\text{Observed mortality \% – Control mortality \%}}{100 - \text{Control mortality \%}} \times 100$

Table 30 TEST FOR LINDANE INSECTICIDE RESISTANCE IN 4th INSTAR LARVAE OF CULEX QUINQUEFASCIATUS COLLECTED AT NIMA.

Tests	Replicate 1			Replicate 2			Replicate 3			Replicate 4			Totals (for comparable tests only)			
Date of test	25·2·81			27·2·81			2·3·81			4·3·81						
Temperature during test (°C)	27 °C			27 °C			27 °C			27 °C						
Insecticide concentration (ppm)	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	M & D	Total	Mort. (%) corr.*	Probit
0·002	3 5	8	26·1	1 6	7	25·0	2 7	9	27·2	1 7	8	26·1	7 25	32	26·1	4·36
0·004	2 11	13	47·8	2 10	12	45·8	2 11	13	45·5	12	12	43·5	6 44	50	45·7	4·89
0·02	15	15	56·5	3 12	15	58·3	13	13	45·5	1 13	14	52·2	4 53	57	53·3	5·08
0·10	1 15	16	60·9	1 14	15	58·3	2 13	15	54·5	17	17	65·2	4 59	63	59·8	5·25
0·50	18	18	69·6	19	19	75·0	18	18	68·2	2 18	20	78·3	2 73	75	72·8	5·61
1·0	1 22	23	91·3	24	24	95·8	22	22	86·4	20	20	78·3	1 88	89	88·0	6·17
2·5	24	24	95·7	2 22	24	95·8	1 22	23	90·9	1 24	25	100	3 93	96	95·6	6·71
Control	2	2	0	1	1	0	1 2	3	0	2	2	0	1 7	8	0	0

(Abbreviations: "M" – moribund; "D" – dead)
Correct by applying Abbott's formula* if control mortality is between 5% and 20% (see instructions).

*ABBOTT'S FORMULA: Corrected mortality % = $\frac{\text{Observed mortality \%} - \text{Control mortality \%}}{100 - \text{Control mortality \%}} \times 100$

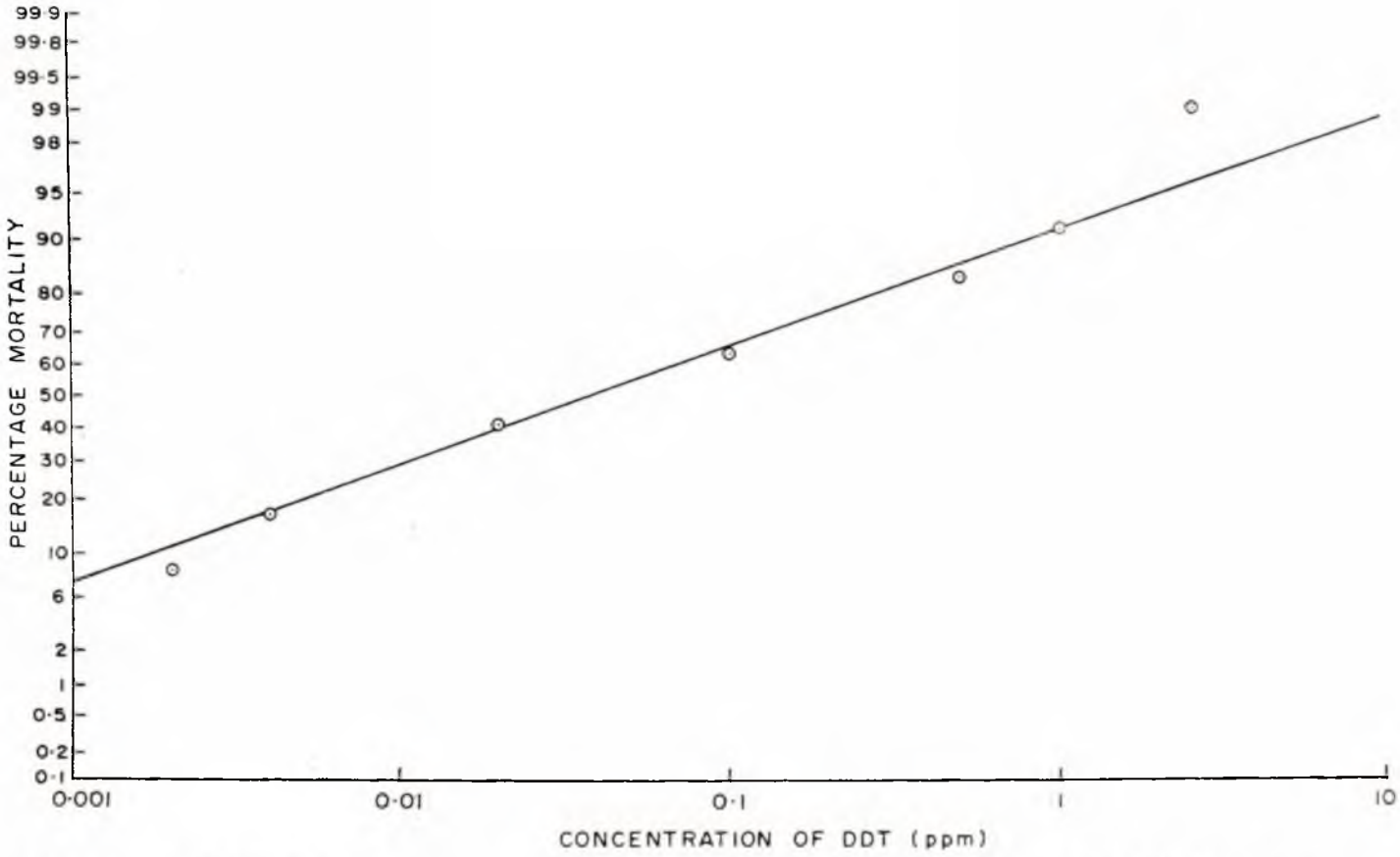

Fig. 11 EFFECT OF DDT INSECTICIDE CONCENTRATION ON MORTALITY OF CULEX QUINQUEFASCIATUS. (24 hours exposure)

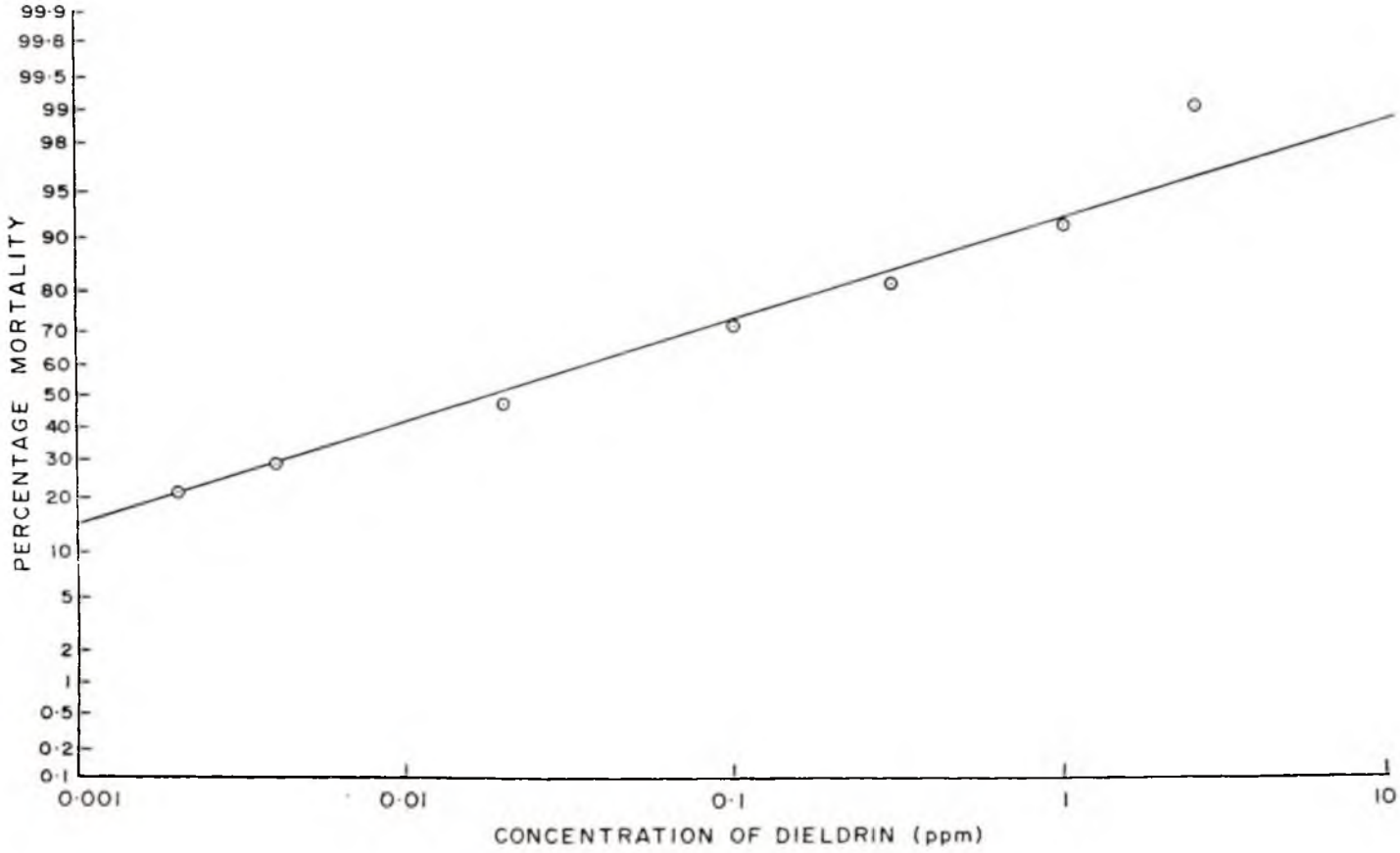

Fig. 12 EFFECT OF DIELDRIN INSECTICIDE CONCENTRATION ON MORTALITY OF CULEX QUINQUEFASCIATUS LARVAE. (24 hours exposure)

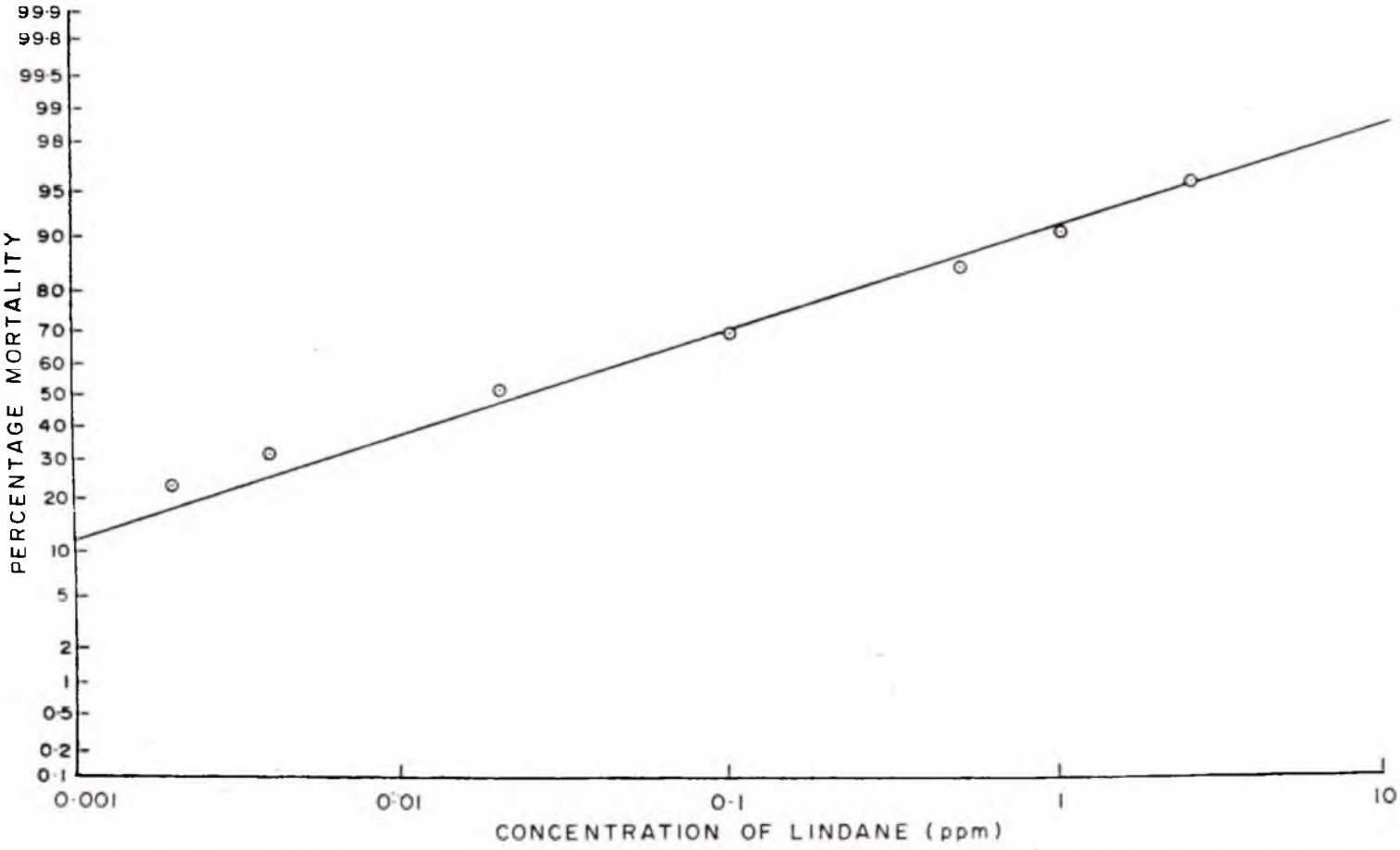

Fig. 13 EFFECT OF LINDANE INSECTICIDE CONCENTRATION ON MORTALITY OF CULEX QUINQUEFASCIATUS LARVAE. (24 hours exposure)

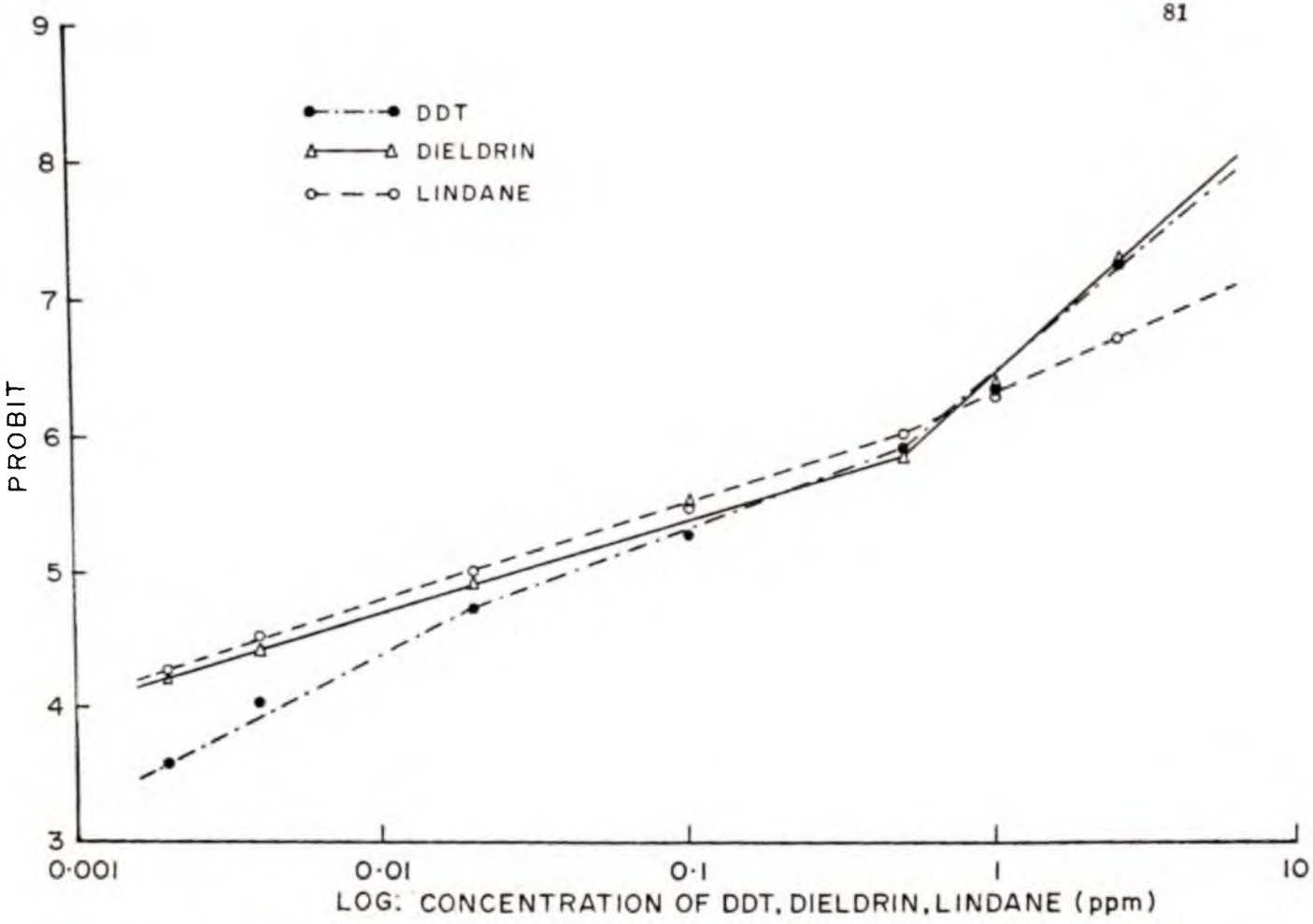

Fig. 14 PROBIT ANALYSIS OF DDT, DIELDRIN AND LINDANE FROM VALUES OBTAINED FROM THE SUSCEPTIBILITY TEST ON CULEX QUINQUEFASCIATUS IN THE LABORATORY.

Table 31: Fitting a Regression line and testing the goodness of Fit

(Data on Susceptibility of mosquito larvae to DDT)

Insecticide concentration. ppm	Insects dead/ tested	Observed mortality rate % corrected	Expected mortality rate % (from graph)	Observed minus expected rate	Contribution to X^2
0.002	17/100	7.7	11.0	-3.3	.01110
0.004	28/100	16.6	16.5	-0.1	.0000072
0.020	47/100	39.9	39.9	0.9	.00034
0.100	66/100	61.1	64.5	3.4	.00500
0.500	85/100	82.1	85.0	2.9	.00659
1.000	93/100	91.1	90.5	0.6	.0004187
2.500	99/100	98.9	95.5	3.4	.0268993
					.0503552

The formula for calculating X^2 for the individual differences is as follows:

$$X^2 \text{(for each difference)} = \frac{(\text{Observed-expected mortalities } \%)^2}{(\text{Expected mortality, } \%) \times (100\text{-Expected mortality } \%)}$$

$X^2 = 0.0503552 = 0.0504$

The average mosquito = 100, the product of 0.0504 and 100 is 5.04

$X^2 = 11.070$

$5.04 < 11.070$

It may therefore be concluded that the line is a good fit and that the data are not significantly heterogenuous.

The LC_{50} = 0.040 ppm

LC_{95} = 2.20 ppm.

CONFIDENCE LIMITS OF THE LC_{50}

The confidence limits between which the LC_{50} may be expected to lie with a probability of 95% may be computed by the method of Litchfield and Wilcoxon (1949). Two qualities must be calculated: the slope function (denoted S) and a factor (denoted fLC_{50}) that is applied as a multiplier to the LC_{50} to give the upper confidence limit and as a divisor, to give the lower limit. The steps are as follows:

(1) The expected LC_{16} and the expected LC_{84} are read from the regression line.

(2) The number of mosquitoes tested at concentrations whose expected effects are between 16% and 84% is ascertained from the table of test data. The number is donoted N.

(3) The slope function (S) is then computed by the formula:

$$S = \frac{LC_{84}/LC_{50} + LC_{50}/LC_{16}}{2}$$

(4) The factor (fLC_{50}) is obtained from the formula

$$fLC_{50} = S^{2.77} / N = S^{exponent}$$

(5) Then, the LC_{50} x fLC_{50} = upper confidence limit, and the LC_{50}/fLC_{50} = lower confidence limit, at the 95% probability level.

The calculation is obtained from the data of Table 28 and the regression line fig. 11 the LC16 is read as 0.0035 and the LC_{84} as 0.43. The number of mosquitoes tested between the two limits N, is 100 + 100 + 100 = 300.

The slope function S = 11.089285

Confidence limit, upper = 0.040 x 1.469 = 0.05876

Confidence limit, lower = 0.040/1.469 = 0.0272294

Therefore, it may be concluded, with 95% probability, that the LC_{50} of 0.040 will lie between the limit 0.059 ppm and 0.027 ppm.

CONFIDENCE LIMITS OF THE LC_{95}

The slope function S = 314.38343

Confidence limit, upper = 2.20 x 2.508 = 5.51760

Confidence limit, lower = 2.20/2.508 = 0.8771929

Therefore, it may be concluded, with 95% probability, that the LC_{95} of 2.20 will lie between the limits 5.518ppm and 0.877 ppm

Table 32: Fitting a Regression Line and Testing the Goodness of Fit (Data on Susceptibility of mosquito larvae on DIELDRIN)

Insecticide Concentration %	Insects dead/ tested	Observed mortality rate % (corrected)	Expected mortality rate (from graph)	Observed minus expected	Contribution to X^2
.002	29/100	21.9	21.9	0.9	.0004882
.004	35/100	28.7	28.5	0.2	.0000196
.020	52/100	47.5	51.0	-3.5	.0049019
.100	74/100	71.4	72.5	-1.1	.0006068
.500	81/100	80.8	84.0	-3.2	.007619
1.00	92/100	91.2	92.5	-1.3	.002436
2.50	99/100	98.9	96.0	2.9	.021901
					.0379725

ΣX^2 = 037925 = 0.0379

The average mosquito = 100 the product of 0.0379 and 100 is 3.79 at 5% probability level and 5 d.f.

X^2 = 11.070

3.79 < 11.070

It may therefore be concluded that the line is a good fit and that the data are not significantly heterogenuous.

The LC_{50} = .019

LC_{95} = 1.80

CONFIDENCE LIMITS OF THE LC_{50}

The slope function(s) is computed by the formula:

$$S = \frac{LC_{84}/LC_{50} + LC_{50}/LC_{16}}{2} = 16.94$$

The factor(FLC_{50}) is obtained from the formula:

$$FLC_{50} = S^{2} .77/N = S^{exponent.}$$

The exponent of the slope function is:

Exponent = 2.77/ 500 = 2.77/22.36 = 0.12388

FLC_{50} = $S^{0.12388}$ = $16.94^{0.12388}$

Confidence limit, upper = 0.019 x 1.922 = 0.0365 ppm

Confidence limit, lower = 0.019/1.922 = 0.00988 ppm.

Therefore, it may be concluded with 95% probability, that the LC_{50} of 0.019 will lie between the limits 0.036 ppm and 0.009 ppm

CONFIDENCE LIMITS OF THE LC_{95}

The slope function(s) is computed by the formula:

$$S = \frac{LC_{84}/LC_{95} + LC_{95}/LC_{16}}{2} = 857.226$$

The exponent of the slope function is:

Exponent =2.77/500 = 2.77/22.36 = 0.12388

FLC_{95} = $S^{0.12388}$ = $857.226^{0.12388}$

Confidence limit, upper = 1.80 x 2.309 = 4.1562

Confidence limit, lower = 1.80/2.309 = 0.7795582

Therefore, it may be concluded, with 95% probability, that the LC_{95} of 1.80 will lie between the limits 4.156 ppm and 0.779 ppm

Table 33: Fitting a regression line and Testing the Goodness of Fit (Data on Susciptibility of mosquito larvae on LINDANE)

Insecticide concentration %	Insects dead/ tested	Observed mortality rate % (from graph)	Expected mortality rate, %	Observed minus expected	Contribution to X^2
.002	30/100	23.0	18.0	5.0	.0169376
.004	38/100	31.8	24.5	7.3	.0288092
.020	55/100	50.6	46.5	4.1	.0067571
.100	72/100	68.1	70.0	-1.9	.001719
.500	87/100	84.7	87.0	-2.3	.0036767
1.00	92/100	90.2	91.5	-1.3	.0021729
2.50	97/100	95.7	95.5	0.2	.000080

X^2 = .0578796

The average mosquito = 100 the produce of 0.0578796 and 100 is 5.788 at 5% probability level and 5 d.f.

X^2 = 11.070

$5.788 < 11.070$

It may therefore be concluded that the line is a good fit and that the data are not significantly heterogenuous.

The LC_{50} = 0.025 ppm

LC_{95} = .210 ppm.

CONFIDENCE LIMITS OF THE LC_{50}

The slope function(S) is computed by the formula:

$$S = \frac{LC_{84}/LC_{50} + LC_{50}/LC_{16}}{2} = 14.775757$$

Confidence limit, upper = 0.025 x 1.718 = 0.04295

Confidence limit, lower = 0.025/1.718 = 0.0145518

Therefore, it may be concluded, with 95% probability, that the LC_{50} of 0.025 will lie between the limits 0.043 ppm and 0.014 ppm.

CONFIDENCE LIMITS OF THE LC_{95}

The Slope function (S) is computed by the formula:

$$S = \frac{LC_{84}/LC_{95} + LC_{95}/LC_{16}}{2}$$

Confidence limit, upper = 2.10 x 2.445 = 5.1345

Confidence limit, lower = 2.10/2.445 = 0.8588957

Therefore, it may be concluded, with 95% probability, that LC_{95} of 2.10 will i.e. between the limits 5.134ppm and 0.859 ppm.

Table 34 Susceptibility of Culex quinquefasciatus to Discriminating Dosage of 1ppm DDT in the Laboratory.

Average mortality (corrected) 81%

EXPT.	NO used	No. of dead	% Mortality	Corrected % Mortality	Date
1.	25	20	80	80	
2	25	21	84	83	
3	25	23	92	91	5/5/81
4	25	22	88	87	
CONTROL	50	2	4	0	
1.	25	19	76	74	
2	25	20	80	78	
3	25	20	80	78	7/5/81
4.	25	22	88	87	
CONTROL	50	3	6	0	
1.	25	21	84	83	
2	25	20	80	73	
3	25	18	72	70	9/5/81
4	25	22	88	87	
CONTROL	50	2	4	0	
1	25	22	88	87	
2	25	23	92	91	
3	25	20	80	78	11/5/81
4	25	18	72	70	
CONTROL	50	3	6	0	

Table 35 Check for Resistance on Culex quinquefasciatus Larval Susceptibility test with 1ppm DDT in the Laboratory

Average Mortality (Corrected) 76%

Expt.	No Used	No Dead	% Mortality	Corrected % Mortality	Date
1.	25	21	84	83	
2	25	18	72	70	
3	25	18	72	70	13/5/81
4	25	19	76	74	
CONTROL	50	3	6	0	
1.	25	20	80	78	
2	25	18	72	70	
3	25	20	80	78	15/5/81
4	25	19	76	74	
CONTROL	50	4	8	0	
1	25	22	88	87	
2	25	20	80	79	
3	25	19	76	74	17/5/81
4	25	18	72	70	
CONTROL	50	3	6	0	
1	25	23	92	91	
2	25	19	76	74	
3	25	18	72	70	19/5/81
4	25	18	72	70	
CONTROL	50	3	6	0	

Table 36 Susceptibility of *F2 Generation" of Culex quinquefasciatus to 1ppm DDT in the Laboratory

Average Mortality (corrected) 62%

Expt.	No. Used	No Dead	% Mortality	Corrected % Mortality	Date
1.	25	15	60	60	
2.	25	17	68	68	
3	25	17	68	68	25/6/81
4	25	16	64	64	
CONTROL	50	2	4	0	
1.	25	14	56	53	
2.	25	16	64	61	
3.	25	16	64	61	25/6/81
4	25	15	60	57	
CONTROL	50	3	6	0	
1	25	17	68	68	
2	25	16	64	64	
3	25	15	60	60	25/6/81
4	25	15	60	60	
CONTROL	50	2	4	0	
1.	25	18	72	70	
2.	25	16	64	62	
3	25	15	60	57	25/6/81
4	25	16	64	61	
CONTROL	50	3	6	0	

* 'F2 " Generation" refers to larvae that were obtained from survivors of discriminating dosage (1ppm) and bred to adult stage in the Laboratory

Table 37 Susceptibility of Culex quinquefasciatus to Discriminating dosage of 1ppm DIELDRIN in the Laboratory

Average Mortality (corrected) 83%

Expt.	No of Mosquito Used	No. Dead	% Mortality	Corrected % Mortality	Date
1.	25	23	92	91	
2	25	23	92	91	
3	25	20	80	79	5/5/81
4	25	20	80	79	
CONTROL	50	3	6	0	
1	25	24	96	96	
2	25	23	92	91	
3	25	20	80	78	7/5/81
4	25	22	88	87	
CONTROL	50	4	8	0	
1	25	21	84	82	
2	25	20	80	79	
3	25	21	84	82	9/5/81
4	25	22	88	87	
CONTROL	50	3	6	0	
1	25	20	80	79	
2.	25	19	76	74	
3	25	18	72	70	11/5/81
4	25	20	80	79	
CONTROL	50	3	6	0	

Table 38 Check for resistance on Culex quinquefasciatus Larval susceptibility with DIELDRIN at 1ppm in Laboratory

Average mortality (corrected) 76%

Expt	No Used	No. Dead	% Mortality	Corrected % Mortality	Date
1	25	17	68	68	
2	25	18	72	72	
3	25	19	76	76	13/5/81
4	25	20	80	80	
CONTROL	50	2	4	0	
1	25	19	76	76	
2	25	18	72	72	
3	25	17	68	68	15/5/81
4	25	18	72	72	
CONTROL	50	2	4	0	
1	25	21	84	83	
2	25	22	88	87	
3.	25	20	80	79	17/5/81
4	25	19	76	74	
CONTROL	50	3	6	0	
1.	25	18	72	70	
2.	25	20	80	79	
3.	25	21	84	83	19/5/81
4	25	19	76	74	
CONTROL	50	3	6	0	

Table 39. Susceptibility of *"F2 Generation" of Culex quinquefasciatus to DIELDRIN at 1ppm in the Laboratory

Average mortality (corrected) 63%

Expt.	No. Used	No. Dead	% Mortality	Corrected % Mortality	Date
1.	25	16	64	64	
2	25	18	72	72	
3.	25	17	68	68	25/6/81
4	25	17	68	68	
CONTROL	50	2	4	0	
1	25	15	60	57	
2	25	15	60	57	
3	25	14	56	53	25/6/81
4	25	17	68	66	
CONTROL	50	3	6	0	
1.	25	16	64	64	
2	25	17	68	68	
3	25	16	64	64	25/6/81
4	25	15	60	60	
CONTROL	50	1	2	0	
1	25	17	68	66	
2	25	18	72	70	
3	25	16	64	61	25/6/81
4	25	15	60	58	
CONTROL	50	3	6	0	

* "F2 Generation" refers to Larvae that were obtained from survivors of discriminating dosage (1ppm) and bred to adult stage in the Laboratory

Table 40 Susceptibility of Culex quinquefasciatus to Discriminating dosage of 1ppm LINDANE IN THE LABORATORY

Average mortality (corrected) 87%

Expt	No Used	No Dead	% Mortality	Corrected Mortality %	Date
1	25	22	88	87	
2	25	21	84	83	
3	25	23	92	91	5/5381
4	25	21	84	83	
CONTROL	50	3	6	0	
1	25	23	92	92	
2	25	24	96	96	
3	25	22	88	88	7/5/81
4	25	21	84	84	
CONTROL	50	2	4	0	
1	25	22	88	87	
2	25	21	84	94	
3.	25	23	921	91	9/5/81
4	25	20	80	79	
CONTROL	50	3	6	0	
1	25	21	84	83	
2.	25	23	92	91	
3	25	19	76	74	11/5/81
4	25	21	84	83	
CONTROL	50	3	6	0	

Table 41 Check for resistance on Culex quinquefasciatus Larval Susceptibility with 1ppm LINDANE in the Laboratory

Average mortality (corrected) 75%

Expt.	No. Used	No. Dead	% Mortality	Corrected % Mortality	Date
1	25	21	84	83	
2.	25	18	72	71	
3.	25	20	80	79	13/5/81
4	25	18	72	71	
CONTROL	50	2	4	0	
1.	25	18	72	70	
2	25	18	72	70	
3	25	20	80	79	15/5/81
4	25	19	76	74	
CONTROL	50	3	6	0	
1.	25	18	72	72	
2	25	21	84	84	
3	25	19	76	76	17/5/81
4	25	20	80	80	
CONTROL	50	1	2	0	
1	25	22	80	80	
2.	25	21	76	76	
3.	25	18	68	68	19/5/81
4	25	18	64	64	
CONTROL	50	2	4	0	

Table 42 · Susceptibility of *F2 Generation" of Culex quinquefasciatus to 1ppm LINDANE in the Laboratory

Average mortality (corrected) 67%

Expt	No Used	No. Dead	% Mortality	Corrected % Mortality	Date
1	25	17	68	68	
2	25	18	72	72	
3.	25	16	64	64	25/6/81
4	25	17	68	68	
CONTROL	50	2	4	0	
1	25	16	64	62	
2	25	15	60	57	
3	25	17	68	66	25/6/81
4	25	18	72	70	
CONTROL	50	3	6	0	
1.	25	18	72	70	
2	25	17	68	65	
3.	25	15	60	57	25/6/81
4	25	16	64	61	
CONTROL	50	4	8	0	
1.	25	20	80	80	
2.	25	19	76	76	
3.	25	17	68	68	25/6/81
4	25	16	64	64	
CONTROL	50	2	4	0	

*"F2 Generation" refers to Larvae that were obtained from survivors of discriminating dosage (1ppm) and bred to adult stage in the Laboratory.

Table 43: Comparison of resistant Culex quinquefasciatus Say larvae in Accra, (Ghana .by R. Esena) with results of WHO Tests for Susceptible larvae from Fiji, when tested with DDT, Dieldrin and Lindane.

	WHO (Fiji)		R. ESENA Accra, Ghana	
Insecticide	LC50 (ppm)	LC95 (ppm)	LC50 (ppm)	LC95 (ppm)
DDT	0.012	0.04	0.036	2.20
DIELDRIN	0.004	0.019	0.01	1.80
LINDANE	0.008	0.025	0.032	0.210

4. GENERAL DISCUSSION AND CONCLUSION.

DISCUSSION

The distribution of larvae within the breeding site is not uniform for the larvae always concentrate around the borders and around different floating objects or vegetation. Here the larvae are seeking some support to avoid movement during feeding or to avoid being displaced by the movements of the superficial layer of the water if there is slight current. The miscroscopic flora and fauna upon which the larvae feed ~~is~~ are more abundant around the vegetation.

In a breeding place where the water moves continuously (such as Nima) the larvae concentrate in those places where they will find a still harbourage especially along the banks. In a large stagnant water collection, first stage larvae are concentrated in places where the eggs were laid, but 3rd and 4th stage larvae move several metres away from the place of hatching and concentrate in the most favourable spots, in the shade or in the light, or near vegetation according to the species' habit. Natural or artificial agitation of the water favours such dissemination of larvae, winds moving the superficial layer of the water will force the larvae to concentrate in quiet corners of the breeding space. Rain might wash out some breeding places or cause flooding, resulting in the larvae being transferred long distances, varying from a few metres to kilometres.

The egg may be transported by fast flowing waters and may be destroyed by throwing them on to dry ground where they are rapidly dried by the sun. When larvae are in an advanced stage of development, they are more resistant to dessication and can survive several days on mud in the shade (Anon, 1975b). This shows how an environmental condition may play an important role in determining the concentration of larvae and why they should therefore be carefully considered when estimating larval density.

It is a well known fact that mosquito populations, both adult and immature stages, are not dispersed at random but occur in concentrations over a wide and variable area. Most insect populations, however, have what is termed a contagious or aggregated distribution, and individuals occur in definite clumps leading to a parchy type of pattern. As most environments are not completely uniform, it is not surprising that certain areas will be favoured more than others and thus contain more individuals than less favoured sites. A characteristic of contagious distribution is a large variability of counts in different samples. In contagious distributions the variance is always greater (many times) that the sample mean ($s^2 > \bar{x}$). The type of contagious distribution may change, for example first instar mosquito larvae may exhibit a more highly contagious distributions than the later instars and pupae.

Quantitative sampling of larval density with the available devices is far from accurate for the following reasons:

(1) Larvae are not distributed at random in breeding places, but are often crowded in concentrated sites. Therefore it is difficult

to extrapolate the data on larvae in the site sampled to all the surface area of each type of the breeding place.

(2) Breeding places vary in size and shape and their surface area fluctuates with seasonal environmental changes. Therefore it is difficult to fix a standard surface area for each type of breeding place. The amount of aquatic vegetation also varies, which increases the difficulty of reliable sampling of larval density.

(3) The behaviour of larvae in the breeding habitats varies with the species.

For the purpose of evaluating larval control measures, the following precautions were taken and should ensure reasonably standardized samples:

(a) Sampling was directed to sites where there are larval concentrations in the breeding places. (This can be ascertained after a wide search for larvae). Those sites having a high density serve as fixed capture stations.

(b) Depending on the local conditions, sampling was made with a ladle at Nima for small water collections and with a net dipper for large collections - as [illegible] at Malam.

It is observed in this project that the *Culex quinquefasciatus* population increases soon after the rains while *C. thalassius* increases during the rains and after, Table 20. At Malam there was a very low

number of *Culex thalassius* on the 24th June 1981 (i.e. 5) as compared with 1,970 on the 17.6.81 (Table 19) This is explained by the very heavy rainfall registered on 23rd June 1981, as 68.6mm. (at Weija) Appendix A. This heavy rain resulted in the overflooding the banks of the pond at Malam with the result that almost all the mosquito populations were flushed to surrounding vegetation. Large numbers of *Notonecta* followed and lasted for 4 weeks. The other aquatic organisms were mainly Cybister spp (larvae and adult), Gerris and Dragonfly nymph. All these aquatic organisms are predators and may explain the continuous absence of mosquitoes from 8.7.81 to 29.7.81 at Malam. (Table 19).

There were unusually high numbers of pupae on the 4.3.81 and 8.4.81 at Malam (Table 19). This may be explained by a drop in 1st and 2nd instar larvae the last few weeks preceeding the dates, which in turn produced a lower number of 3rd-4th instar larvae on the respective dates 4.3.81 and 8.4.81. Unfortunately there were no numerical records but mere observations only. Another probable reason for the high number of pupae may be due to sustained high number of 3rd and 4th instar larvae in the weeks preceeding the 4.3.81 and 8.4.81. The usual lower number of pupae reflects the mortality pattern exhibited in the laboratory experiment on cohort analysis (Tables 11 and 12)

The dominant mosquito species at Malam is *Culex thalassius*. A few other mosquito species emerged. They were *C. decens*, *C. duttoni*

and *C. quinquefasciatus* but they were all eliminated after the 4.1.81. *Aedes albocephalus* emerged on the 6.5.81 but disappeared on the 20.5.81 when *C. thalassius* reappeared in large numbers.

Measurements were made of the depth of the pond at Malam. There was a gradual decrease in depth from 2.5 metres on the 6.8.80 to 1.65 metres on the 25.2.81. However, it increased again to 3.1 metres on 27/5/81 when the rains began.

Unfortunately instars were not recorded for Malam until the 20.5.81 because interest was earlier directed towards *Culex quinquefasciatus* only.

The survivorship curve for Nima (fig.5) based on the yearly total instars is not as expected. The value expected for the 1st and 4th instars larvae were 32,146 and 2,143 even though 6,964 and 2,677 were observed. The graphs figs. 3 and 6 depict that of the laboratory and Malam respectively.

At Nima, two mosquito species coexisted throughout the year. They were *Culex quinquefasciatus* and *C. tigripes*. As Table 20 shows, their numbers rose to very high peaks before and after the rains. This could be explained by the fact that there is constant flushing during the rainy season which did not allow the mosquitoes to remain at one place. Another possibility may be due to the fact that *Culex quinquefasciatus* and *C. tigripes* larvae may thrive better in highly polluted environment. The sudden drop in numbers on the 18.2.81 and 5.8.81 (Table 20) may be due to the heavy rains registered on the 16.2.81 as 16.3mm and on 2.8.81

and 3.8.81 as 0.3mm, Appendix B. The population decreased considerably between the 18.3.81 and 22.7.81 (Table 20).

Many factors can determine the fate of a population. According to Andrewartha (1961b) there are 4 major factors as follows: food, climate, the action of other animals and pathogenic organisms, and living space.

Subra (1970) studied the influence of these factors on *Culex pipiens quinquefasciatus*. One factor associated with crowding could have influenced the tank population of his study. Roubaud and Toumanoff (1930) first observed in the laboratory that the accumulation of toxic wastes excreted by larvae of *C.p. pipiens* could retard and even cause mortality among larvae. Subra (1970) tested for the possible effect of a toxic substance associated with the larval exuviae, but no significant effect could be found. Of all factors studied, the only demonstrable intrinsic factor was the toxic effect of the wastes of older larvae, which Hayes (1975) reported as being variable and operating for a relatively brief period. Very definite toxic effects of 3rd instar larval waste upon 1st instar larvae were demonstrated by Ikeshoji and Mulla (1970). In addition to production of toxic wastes, overcrowding slowed down growth and development of younger larvae and produced morphological aberrations in larvae.

Build-up of surplus food is associated with crowding. Excess food could induce microbial fermentation which, according to Subra (1970)

would render the water unfit for the production of pupae. Subra contends that the larval habitat can become too polluted for *C. p. quinquefasciatus*. Both microbial fermentation and larval waste products could have affected the laboratory population and cohort equally. The mortality in the laboratory population reared in beakers is partially attributed to crowding, which probably resulted in reduced feeding in some of the instars. Unfortunately, the weight of food (farex and ceralac) given in each group was not recorded.

Crowding of immature stages is considered to be one of the main causes of migration or dispersal (Johnson 1966, 1969, Wada 1965). The studies of Nayar and Sauerman (1973) demonstrate that crowding of larval *C. p. quinquefasciatus* resulted in increased flight activity of females. Such phenomenon could possibly have operated in the present study and might have reduced the number of females returning to the site to deposit eggs and therefore enhancing larval fluctuation.

Very few investigations have been made into instar moralities of mosquito larvae, but in Nigeria and Kenya mortality of the pre-adults of Anopheles gambiae complex was greatest in 4th instar (Service 1971, 1973, 1976). In Bangkok, during the cooler months, mortality of *Aedes aegypti* was greatest in fourth-instar collected from water jars and ant traps, but in the hot season mortality was more intense in the first-instar in the water jars (Southwood et. al. 1972). However, in this experiment

the highest mortality occurred between the pupae and adult stages with K-value 0.24 Table 11.

Under overcrowded conditions, older larvae of *Culex pipiens* Wiedeman elaborate chemicals known as 'overcrowding factors' which are toxic to first-instar larvae and produce growth-retarding effects in young larvae (Hwang et. al, 1976). The same'overcrowding factors' is suspected to operate in this experiment. Probably this toxic effect could cause the mortality in the pupal stage which does not feed.

The efficacy of natural enemies is higher when the biotype and the behaviour of larvae and predators favours close contact, for example, guppies Paecilia *reticulata* are surface feeders as are mosquito larvae, therefore the area of activity of the predator and the prey is the same. Predators which live at the bottom of the breeding sites are less efficient. The smaller the volume of water in which the natural enemies and mosquitoes live, the more efficient the predator activity. The presence of other insects on which the predators feed reduces the impact of the predators on the mosquito population. For example, Notonecta and Cybister spp. larvae feed on other younger predators. Also at Nima, guppies may feed on Notonecta, *Culex quinquefasciatus*, *C. trigripes* and younger larvae of Syrphidae - to mention a few. Also the efficacy of the predator varies with the environment which might increase or decrease the possibility and duration of contact between predators and mosquitoes. At Nima for example, there is quite

a number of Notonecta, guppies, *Culex tigripes* and *C. quinquefasciatus* but they all seem to live quite successfully in the water, even though it is expected that *C. quinquefasciatus* is preyed upon by the other predators. This may be due to the competitive exclusion principle whereby each of these organisms live at different zones in the environment (Boubjerg, 1970). The large numbers of *C. quinquefasciatus* compared with *C. tigripes* may be due to reproductive rate of *C. quinquefasciatus*.

It is a well known fact that under the influence of environmental conditions a vector species may show changes in the seasonal distribution in the same area of dominance. The increase in density of a vector species is very much dependent on climatological factors favourable for its breeding, and adult survival. An exceptionally heavy rainy season might be favourable to the development of a number of species (e.g. Notonecta) yet detrimental to others (.e.g. the mosquito larvae).

The climate is one of the major components of the physical environments, and is a composite condition of which temperature, relative humidity, precipitation, light and wind are the important components. The daily expression of climate is called "weather" and this has a profound impact on the biology, distribution and density of a mosquito species at any given time (Annn, 1975a). The climate can be divided into 2 types. (i) macroclimate, which means the average weather conditions of an area, and (ii) microclimate, or modifications in restricted areas within the overall macroclimate zone. There are two major climates - wet and the

dry season. It is therefore not enough to find the effect of climate on the mosquito incidence. However during the raining season the larvae are constantly flushed in the Nima drain(Table 20)but mosquitoes in the pond at Malam(Table 19)are not affected.

Insects are cold-blooded and therefore all metabolic processes and the entire vital cycle depends on the environmental temperature. Mosquitoes, like the majority of insects are unable to control the body temperature of their bodies to a great extent. The insects can survive low temperatures but their metabolic processes are slowed down or even arrested when temperature falls below the threshold.

Humidity can act as a limiting factor in distribution and longivity. Owing to the tracheal system of respiration, insects in general are particularly susceptible to dessication, even though forest species are more susceptible to humidity changes than those living in areas with dry climate (Anon, 1975a).

The effect of rainfall varies according to its amount and the physical features of the terrain. Repeated rain causes severe flooding, resulting in temporary flushing out of the breeding places. Consequently, the breeding of a vector population is greatly reduced but it will soon be re-established when normal conditions are restored. Moderately frequent rainfall but with fairly long periods of sunshine will increase the opportunity for prolific breeding (Anon 1975a).

Although circadian rhythms have been found to play an important role in controlling most mosquito activities (Anon 1975a, Hayes & Downs, 1980) the effect of light can generally be correlated with movement of mosquitoes for feeding or resting.

Many species tolerate relatively wide temperature fluctuations, but extremes of heat or cold restrict the times and places where larvae can survive and thrive. Other physical and chemical factors that affect larvae and pupae include salinity, pH, hardnes of water, aeration, pollution, movement of water and light intensity. The specific limits within which certain species tolerate such factors merit further investigation as aid to the better understanding of the occurrence and distribution of the species concerned. Temperature (especially minimum temperature) seems a good indicator for predicting densities of a population of *Culex pipiens quinquefasciatus* (Hayes and Hsi, 1975).

Knowledge of the ways in which the various physical and environmental factors discussed in this project affect the immature stages of mosquitoes could certainly be utilized to design appropriate alterations of the environment. Such changes, effected by drainage, filling, removal of vegetation and shade, water-level fluctuation, or related measures, have been used successfully for reducing mosquito numbers. Because of their extremely important implications, they merit the most careful considerations from the earliest planning stage in any water management project (Anon, 1968).

Life-Table analysis is needed in biological control for predicting population level. It is important in Life-Table to sample the population regularly throughout the season and to have a continuous record of reproduction and of mortality factors. This is more elaborate but not different in principle from the "index of population trend", suggested by Balch and Bird (1944). The life-table tells us what happened in a particular year but does not enable prediction of future changes, though it gives expectation for further life.

When lx (Number of Population Surviving at age X) curves are compared, two important points emerge (i) The survivorship of animals in nature sometimes, but by no means always follows the J-shaped distribution (Pearl's 'Type B') resulting from extremely heavy mortality at early stages. Diagonal lx curves (Pearl's 'Type B') are evidently frequent in natural as well as in laboratory populations (ii) the form of lx is strongly affected by its point of origin. Bird populations, for example, can be considered from the time the eggs are laid, from hatching, from fledgling, or from breeding age, and correspondingly different life-tables will result.

The central requirement of life-table work is absolute population estimation. As the fiducial limits of such estimates may be wide, it is always of value, whenever possible, to make estimation by more than one method, this also helps to ensure that part of the population

is not totally overlooked. The internal consistency of the life-table provides yet another check on the reliability of the estimates. However, relative estimates are affected by so many factors that they are of limited use for the construction of a life-table. Since much of the previous work on mosquitoes has emphasized relative methods, studies aimed at the construction of a life-table will initially have to be based on techniques developed for other animals. The aims of such study will be to provide estimates of absolute population and to assess the density of the vector in relation to disease transmission and biting.

In Constructing Survivorship Curves and Life-Tables of immature stages of a mosquito population, it is essential that all instars (age class) are sampled with equal intensity to ensure correct figures. However, it has been shown that, at least in some species, the degree of aggregation of the different larval instars and pupae differ considerably, moreover they may occupy different parts of the habitat. Such behaviour will tend to bias the collection of various age groups in samples at the expense of the others. Moreover, it has been shown that, young instar larvae can remain submerged much longer than can older instars (because the younger instar can rely also on cuticular respiration). Consequently, when samples are taken at the water surface, the younger instar larval population will be under-estimated. The escape reaction of the instars may also differ.

In this project, intensive work on Life-Tables was carried out both on the field and in the laboratory. Daily observations and records were made in the laboratory as presented in Table 14. Detailed results are found in tables 15, 16, 17 and 18. The age distribution and survivorship curve of immature stages of *Culex quinquefasciatus* in the laboratory is presented in Figs. 3 and 4 and field experiments of *C. quinquefasciatus* and *C. thalassius* are in figs. 5 and 7, respectively.

The summary for the data at Legon, Chorkor Lagoon, Malam and Nima are presented in Tables 3,4,6 and 9 respectively.

Most of the values obtained were not what was expected. This may not be due to wrong sampling because it was actually observed on the field. On the other hand, it could either be attributed to aggregation of the pupae or some unknown factors operating in the field.

This may be explained by the fact that apart from Table 9 (Data from Nima) and Table 3 (Legon) the decrease is not in a constant trend of reduction. The data from Chorkor Lagoon (Table 4) show that on three occasions, there were gradual trends in decrease. Emphasis was therefore laid on day 7-11 as found in fig.9 because it shows a uniform population reduction. Referring to Table 2 used to analyse the Life-Table, the observed values of 1st instar larvae and pupae of 8,087 and 1652 respectively were expected to be 16,517 and 2,870 respectively (Fig.9).

At Malam, 1st instar larvae and pupae from day 5-15 were observed to be 36,440 and 1,587 respectively even though 62,797 and 12,530 were expected (Fig.8). At Nima between day 2-6 the respective values observed for 1st and 4th instar larvae were 17,069 and 4,963 even though 62679 and 3991 were expected respectively (fig.6).

In these Life-Table studies, it appears that errors were found only in the first instars and late instar stages.

At Legon Fig.10 the expected value for the 1st instar is 1469 and that for the 4th instar is 121. At Chorkor Lagoon, the expected value for the 1st instar is 53831, the value for the 4th instar is 6,325 and the pupae is 4,446.

The expected values for Nima and Malam are illustrated on the graphs figs. 5 and 7 respectively.

I wish to emphasize that the expected values obtained from the graphs could be markedly affected by the accuracy of the experiment on duration of larval instars Tables 8 and 13. Slight errors in the duration of larval instar could affect the expected values. It is noted with quantitative support that the period of instar duration is affected by the temperature (Service, 1977).

At big water bodies such as Chorkor Lagoon for instance, the values obtained for sampling are influenced by waves, unusual flooding and even by fishermen. It is therefore not surprising that the larval population decrease followed 3 trends (Tables 4): day 1-5, day 7-11

and day 15-17. This fluctuation may also be due to addition of newly hatched eggs. The graph (Fig. 9) was plotted to represent day 7-11.

The stages of an insect normally provide the most powerful tool for analysing the seasonal changes in numbers. Moreover, if the relation of instar-length and temperature is determined experimentally, it will be possible to predict the mean lengths of the instars at the prevailing field temperatures by using the formulae of Davidson (1944).

The methods of dealing with the determination of age structure and mortality have been devised by Dempster (1956). Richard and Waloff (1954) worked on population exposed to steady state.

Traps based on the habit of larvae ascending to the surface have generally not given satisfactory samples of larval populations. Some traps have been designed to endorse a volume of water having a standard surface area; the contents of such traps can be removed and sieved. Alternatively, a base plate can be inserted into the submerged trap and the water allowed to drain away as the trap is removed. The available traps are not ideal, and new methods of collecting larvae are required. The light trap devised by Service (1981) and tried at Chorkor Lagoon and Malam is very efficient and should therefore be used for Life-Table studies. The effectiveness of the light and sticky traps were compared on the field at Chorkor Lagoon (Table 23). In each case, the variance (SD^2) is much greater than the mean ($\bar{x}$) (Table 25.) This shows that the difference between catches is not by chance of random distribution but as a result of difference in effectiveness of

the traps. Unlike the sticky trap which is most efficient for pupae and younger instars larvae, the light trap is very efficient for all instars. Values obtained from experiments at Chorkor, Table 23, confirm this. In the laboratory 85% larvae in the sink were trapped with the light trap compared with 10% of the original pupae (Table 21). Experiment with the sticky trap in the laboratory gave 100% of trapped pupae and 60% of larvae, but the ratio of larvae to pupae in the sticky trap was 37:63 (Table 22). The light trap is therefore better for larvae while the sticky trap is efficient for pupae.

Field experiments with light and sticky traps confirm the efficiency of light trap for larvae and sticky trap for pupae (Table 24). However, light trap is more efficient for trapping mosquito larvae than the sticky trap. Field experiment with light trap shows that the ratio of larvae: pupae caught was 78:22 while the sticky trap gave a ratio of larvae: Pupae as 38:62 (Table 23).

Physico-chemical studies made at Nima and Malam, Table 26, show that *Culex quinquefasciatus* and *C. tigripes* prefer water with high pH i.e. slightly alkaline (pH 7.1-8.0) while *C. thalassius* prefers slightly acidic water i.e. (pH 3.2-6.9) and high sodium (Na^+) and chloride ion (Cl^-) contents.

Also *C. thalassius* thrives in the soil of a higher organic matter content, as compared with *C. quinquefasciatus and C. tigripes* (Table 27)

One should bear in mind that the chloride content fluctuates from time to time and is much influenced by the rain.

Strictly speaking, one cannot compare the values of the 2 sites - Nima and Malam. Apart from the differences in sampling methods, Nima is a drain while Malam is a pond. *Culex quinquefasciatus* breeds at Nima while *C. thalassius* breeds at Malam. The difference in sampling method could equally affect the results of the Life-table.

The relationship between rainfall, Relative Humidity, temperature and period in months over the past 7 years has been represented in the graph Appendices C & D. App. E represents the data throughout the period of study at Nima.

The objectives of insecticide susceptibility tests are:

(1) To establish baseline susceptibility level of larvae in areas where larviciding has to be applied.

(2) To detect any change in susceptibility level of larvae in areas where larviciding is applied correctly but larvae are still found.

Larvae of *Culex pipiens quinquefasciatus* are less susceptible to DDT than are most other Culicines such as *Aedes aegypti*. The lowest LC_{50} values for *C.p. quinquefasciatus* were recorded for laboratory strains - viz; 0.025 ppm for a colony bred strain at Lagos, Nigeria (Elliot 1955) and 0.03 ppm for a Rangoon strain selected for susceptibility (Tanado and Brown 1967). The lowest LC_{50} of DDT found in wild

strain were 0.04 ppm at Maracay, Venezuela (Blazquez, 1958), 0.045 ppm at Visalia, Calif (Gjullin and Peters 1952) and 0.045 at Tampin, Malaya (Wharton, 1955); on one of the many samples taken at Rangoon, Burma, showed an LC_{50} as low as 0.0025 ppm (Rosen, 1967). Moreover, this species breeds in polluted water, in which it is more difficult to kill the larvae with DDT (Hurlbut and Bohart, 1945), the mortality decreasing as the concentration of total solids increases (Parthasarathy and Krusé, 1954) In Malaya, Reid (1955) was unable to control *C. p. quinquefasciatus* larvae in drains at Klang and Kuala Lumpur even with DDT at 2.25kg/ha, the abundant organic matter undoubtedly being partly responsible (however, both HCH and dieldrin were effective). In British Guiana, Giglioli (1948) could not obtain a persistent effect with DDT in pit latrines at Lodge Village, near Georgetown.

Repeated experimental results on susceptibility of *C. quinquefasciatus* to DDT, DIELDRIN and LINDANE in this project in Tables 28, 29 and 30 and Figs. 11, 12, 13 respectively show that the LC50 of DDT is 0.040 ppm and LC_{95} = 2.20ppm. The upper and lower confidence limits for LC_{50} are 0.059 ppm and 0.027 ppm, while the upper and lower confidence limits of LC_{95} are 4.156 ppm and 0.779 ppm. The LC50 and LC_{95} for DIELDRIN are 0.019 ppm and 1.80 ppm respectively. The upper and lower confidence limits for LC_{50} are 0.009ppm and 0.036ppm while the upper and lower confidence limits for LC_{95} are 0.779 ppm and 4.156 ppm respectively. Tables 31, 32 and 33 give data on susceptibility of DDT, DIELDRIN and LINDANE respectively. They explain the fitting of regression line

and testing the goodness of fit.

The LC_{50} and LC_{95} for LINDANE are 0.025 ppm and 2.10 ppm respectively. The upper and lower confidence limits for LC_{50} are 0.043 ppm and 0.014 ppm while the upper and lower confidence limits for LC_{95} are 5.134 ppm and 0.859 ppm.

Apart from probable errors that could affect the results of the susceptibility tests, improper mixing of the insecticides could also affect the results. However, there is evidence to show that *Culex quinquefasciatus* has developed resistance to all the insecticides tested - DDT, DIELDRIN and LINDANE. Discriminating dossage from probit analysis (Fig. 14) of 1ppm gave about 80-98% (81-87% av.) mortality in each case. (Tables 34, 37, 40). Further check gave average mortalities of 76%, 76% 75% for DDT, DIELDRIN and LINDANE respectively. (Tables 35, 38, 41). Susceptibility for "F2 generation" at 1ppm gave average mortality of 62%, 63%, 67% for DDT, DIELDRIN and LINDANE respectively. (Tables 36, 39, 42). The values obtained for discriminating dossage and verification conform with the WORLD HEALTH ORGANIZATION (WHO) standard test for resistance (Anon 1975a). This aparent resistance may be due to the indiscriminate use of insecticides and also other chemicals used in and around Accra.

Conclusion:

From observations made on the correlation of climatological data and the mosquito population, it is concluded that, rainfall has an influence or control on the mosquito population. Thus very high rainfall tends to reduce the mosquito numbers; but encourages increase of aquatic predators such as Notonecta and Cybister spp.

For an effective work on Life-Table, absolute population numbers, but not relative numbers should be considered.

Quantitative analysis show that *Culex quinquefasciatus* has developed resistance to DDT, DIELDRIN and LINDANE.

Culex quinquefasciatus prefers water with high pH ie. slightly alkaline while *C. thalassius* prefers slightly acidic water and high sodium and chloride ion content.

Light trap is more efficient than sticky trap for mosquito larval sampling.

5 SUMMARY

1. Mosquito larval populations at Nima and Malam have been investigated. The main species at Nima are *Culex quinquefasciatus* and *C. tigripes*, but *C. quinquefasciatus* is dominant. The dominant species at Malam is *C. thalassius*.

2. It is observed that the climate has influence on the larval populations, especially rainfall. The larvae are usually flushed off after heavy rainfall. At Nima rainfall registered at 5.3mm on 14/2/81, decreased the larval population of *Culex quinquefasciatus* from 2,664 on 11/2/81 to 15 on 18/2/81.

Similarly at Nima, rainfal at 22.6mm and 0.8mm on 24/8/81 and 25/8/81 respectively reduced the population numbers from 2,884 on the 18/8/81 to 840 on the 26/8/81.

At Weija, rainfal at 5.3mm on 26/11/80 reduced the mosquito population of *Culex thalassius* in the pond at Malam from 2,275, on the 19/11/80 to 623 on the 26/11/81.

Finally a heavy rainfall of 68.6mm registered at Weija on the 23/6/81 decreased the mosquito population from 1970 on the 17/6/81 to 5 on the 24/6/81.

3. Life-table studies made at the field and also in the laboratory revealed that the early instars are more numerous than the late instars however, there is a heavy mortality at the early stages. At Nima (fig.5) a year's observation of *Culex quinquefasciatus*,

revealed that even though 32, 146 was expected for the first instar 6,964 was observed.

Again 2,143 was expected for the fourth instar though 2,677 was observed. At Malam (fig. 7) a year's observation on Culex thalassius shows that 12,603 was observed for the first instar larvae instead of 23,875 as expected. The expected value for the fourth instar was 2,958 though 4,345 was observed.

With life-table, ecologists can determine the expectation for further life (e^o) in the instars of mosquito for control programmes. Life-table also enables ecologists to have an idea of the mortality and natality of various mosquito species.

4. Comparing the sites and data at Nima and Malam, one observes that the pond at Malam is a large but stagnant water body while at Nima the water body in the drain is less but fast flowing and favours Culex quinquefasciatus.

There is virtually no pollution at Malam, however, it is a clean and brackish water. There is pollution at Nima. The soil organic matter at Malam was 0.7253 while that at Nima was 0.3251.

At Malam there are more sodium (Na^+) ions (15,000ppm) and Chloride (Cl^-) ions (9.95ppm) in water while at Nima, there are less sodium (Na^+) ions (370), and Chloride (Cl^-) ion (0.55ppm).

Malam favours the existence of *Culex thalassius* and many other aquatic organisms such as Dragonfly, Notonecta, Gerris, Hydnometra, Nepa, Rhagovelia, Coenagridae and Cybister larvae and adult. Nima on the other hand has less aquatic life: They are tadpoles, Guppies, Syrhidae, Tetanoceridae, Chironomidae and Notonectidae. *C. quinquefastiatus* and *C. tigripes* coexist in the Nima drain even though *C. quinquefasciatus* is dominant. There are more predators at Malam but less predators at Nima.

At Malam mosquito population increases during the rains, while at Nima, mosquito population increases after the rains.

5. At Chorkor Lagoon, the effectiveness of light and sticky traps was compared using statistical analysis. It was found that the light trap is more efficient than the sticky trap.

In the laboratory 85% of larvae were trapped with the light trap compared with 10% of the pupae. Experiment with the sticky trap in the laboratory gave 100% of trapped pupae and 60% of larvae, but the ratio of larvae to pupae in the sticky trap was 37:63.

Field experiments with light and sticky traps confirm the efficiency of light trap for larvae and sticky trap for pupae. However light trap is more efficient for trapping mosquito larvae and pupae than the sticky trap. Field experiment with light trap shows that the ratio of larvae: pupae caught 78:22 while the sticky trap gave a ratio of larvae: pupae as 38:62.

6. Insecticide susceptibility tests on *Culex quinquefasciatus* larvae were made using DDT, DIELDRIN and LINDANE. The LC_{50} were 0.040ppm, 0.019 ppm and 0.025 ppm respectively. These values were higher than found for susceptible populations and imply an incipient level of resistance.

6 RECOMMENDATIONS

For the purpose of mosquito control measures, the following recommendations are made.

(1) Research should be made in the use of phytoplankton (or vegetation) for biological monitoring of the extent of water pollution, the type of mosquito present, and their seasonal incidence. This would help to predict when control measures should be carried out.

(2) At Malam, large population of Notonecta and Cybister emerged during the heavy rains; and they reduced the mosquito population almost to completion.

It is therefore desirable to study the Biology of Notonecta and Cybister (with emphasis on their Life-Table) to find out how potential they are for controlling mosquitoes.

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9. APPENDICES.

APPENDIX A

DAILY RECORD OF RAINFALL (millimetres) AT WEIJA AT LATITUDE 5° 34′N, LONGITUDE 0° 21′W. AND ALTITUDE 71 METRES AS OBSERVED DURING THE PERIOD OF STUDY AT MALAM, 6TH AUGUST, 1980 THROUGH 5TH AUGUST, 1981.

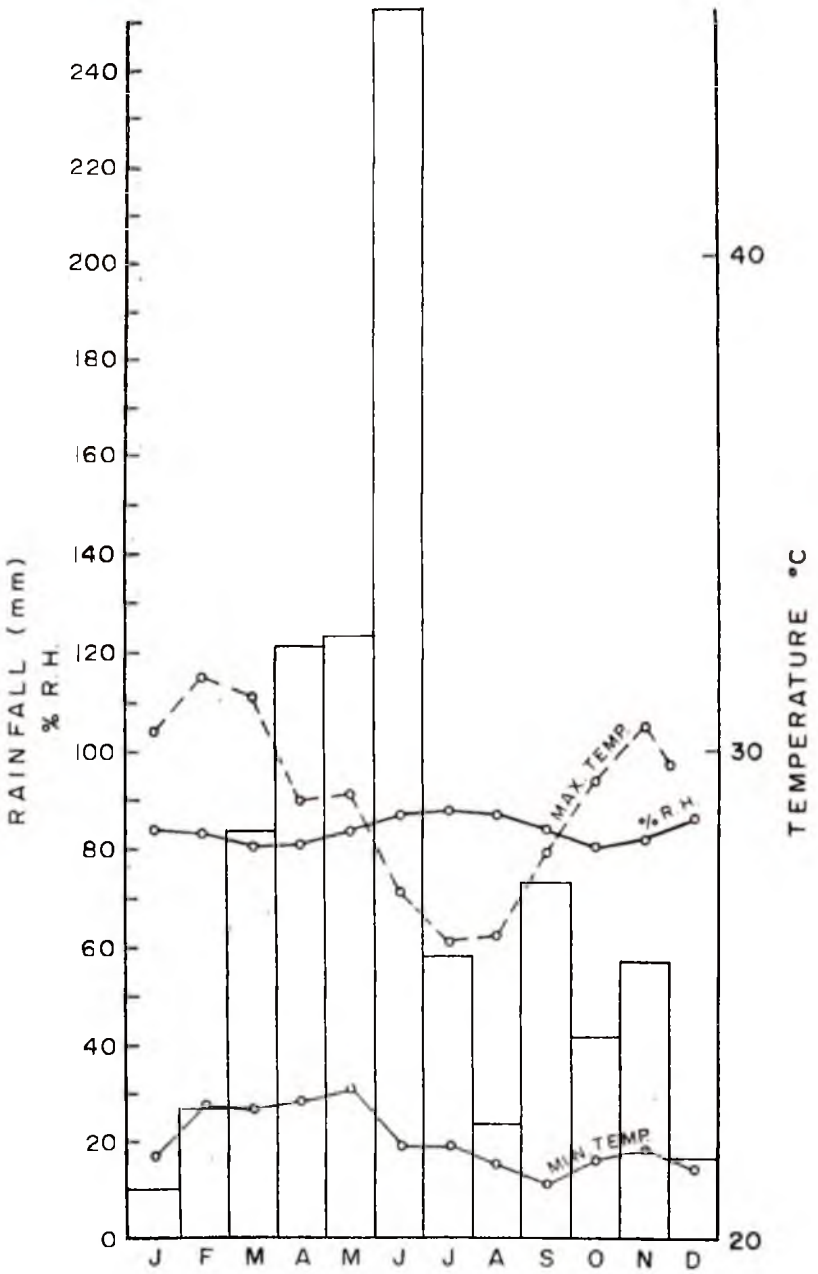
	1980					1981							
Date	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm	mm.
1													
2										21·6			
3													
4											19·3		
5										1·0			
6											4·1		
7				26·4							11·9		
8										47·5			
9	32·8											24·6	
10	4·6									21·8	16·8		
11										42·2			
12		8·1											
13		35·1									45·2		
14													
15													
16				9·7									
17													
18													
19										21·6			
20									15·5				
21		7·1								1·0			
22													
23	23·9	7·4									68·6		
24													
25		4·1							4·6				
26				5·3						59·9			
27		2 5				2·7				4·0			
28													
29							x x						
30	24·1						x x						
31		x x		x x			x x		x x		x x		
Totals(mm)	85·4	64·3		41·4	0	2·7		0	20·1	220·6	165·9	24·6	
Days with 0·2 mm or more	4	6		3	0	1		0	2	9	6	3	
Days with 1·0 mm or more	4	6		3	0	1		0	2	9	6	3	

APPENDIX B

DAILY RECORD OF RAINFALL (millimetres) IN ACCRA AT LATITUDE 5° 36′ N, LONGITUDE 0° 10′ W. AND ALTITUDE 67 METRES AS OBSERVED DURING THE PERIOD OF STUDY AT NIMA, 10TH SEPTEMBER, 1980 THROUGH 9TH SEPTEMBER, 1981.

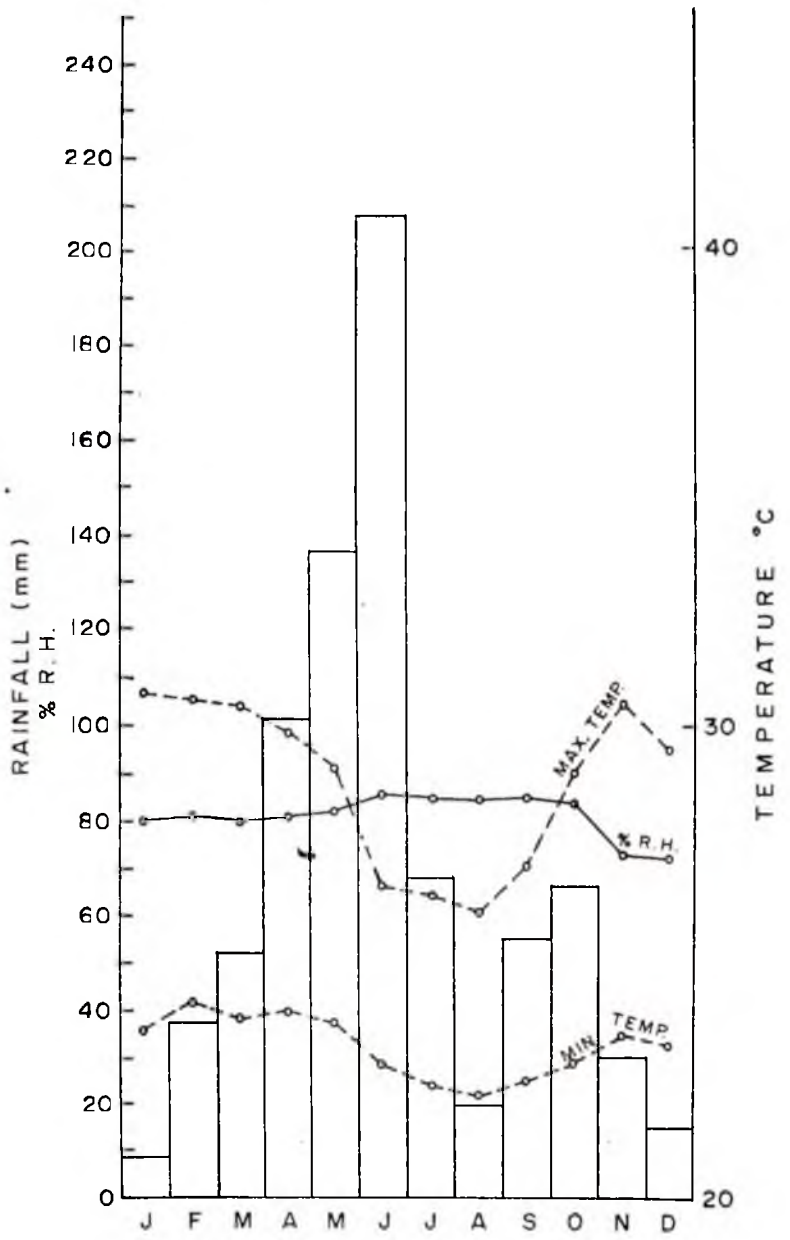
	1980				1981								
Date	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
	mm.	mm.	mm.	mm	mm	mm.	mm	mm	mm.	mm	mm.	mm.	mm.
1		8·9											
2		3·1							15·0			0·3	
3		23·9								2·3		0·3	
4		0·5							14·8	1·3			
5											1·3		
6		3·3	18·0					4·3	0·5	3·0	0·3		
7				1·5					2·5	15·7	60·8		18·8
8						5·1							
9									7·9		1·1	0·5	
10									24·6	16·8	0·3		
11	2·3												
12	1·3			5·8			16·5						
13	46·5		3·8							44·7			
14													
15	0·8		6·3						1·5	0·3		30·9	
16	0·8	0·8				6·3							
17		1·0					0·3		0·5	23·1	1·5	24·4	
18		7·9							29·0		1·8	0·5	
19			1·3					13·5	3·8	3·8	7·6		
20										8·4	5·4		
21	3·0	22·6					6·1		19·0		0·3		
22	3·1	2·5	16·0								0·8		
23			1·5							24·9			
24	2·5							1·0					
25	8·9						1·1		3·1	0·3			
26	1·6				2·0				14·9				
27	12·9						15·3	4·6	3·1		2·8		
28													
29						x x							
30						x x							
31	x x		x x			x x		x x		x x			x x
Totals(mm)		76·0	45·4	7·3	2·0	11·4	39·3	23·4	140·2	144·6	84·0	56·9	
Days with 0·2 mm or more		11	5	2	1	2	5	4	14	12	12	6	
Days with 1·0 mm or more		9	5	2	1	2	4	4	12	10	8	2	

APPENDIX C



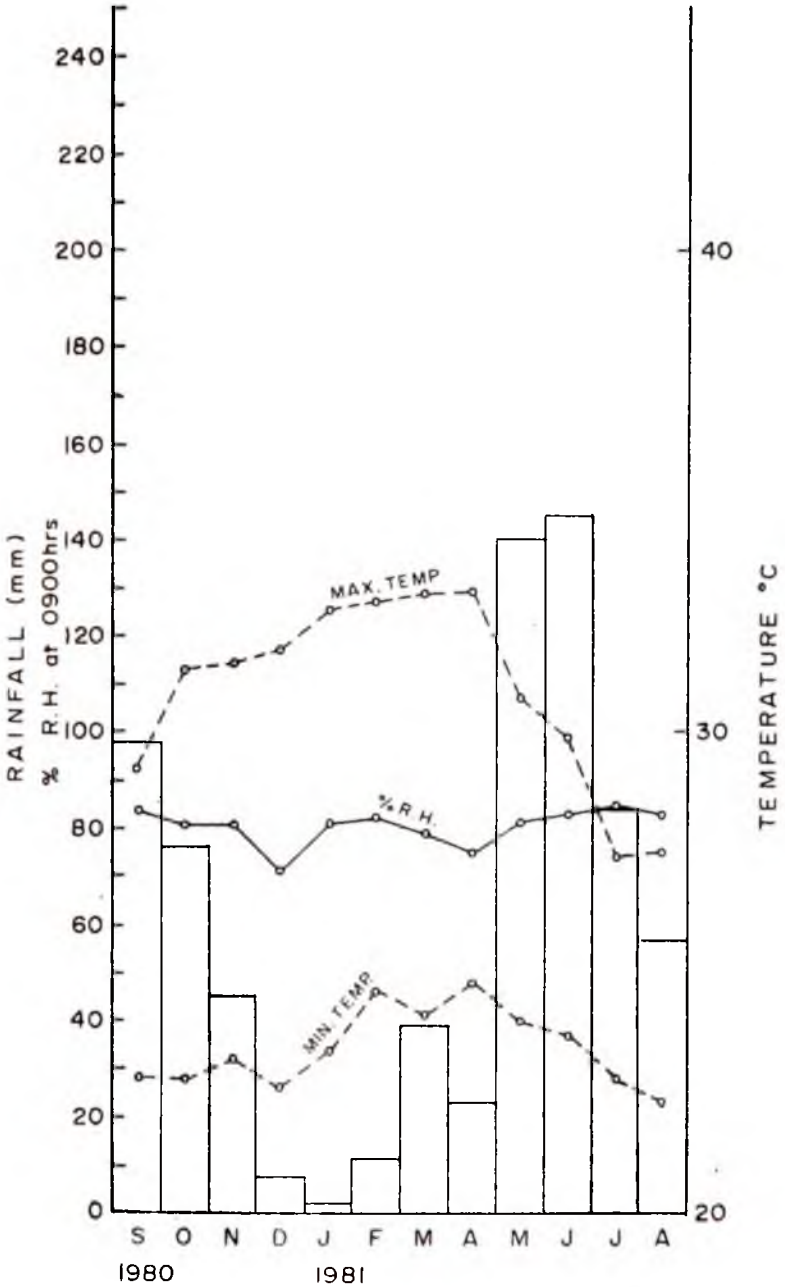
MEAN MAX.– MEAN MIN. TEMPERATURE, RELATIVE HUMIDITY AND RAINFALL AT WEIJA 1970 – 1977 (Average)

APPENDIX D.



MEAN MAX. – MEAN MIN. TEMPERATURE, RELATIVE HUMIDITY AND RAINFALL AT ACCRA 1970 – 1977 (Average)

APPENDIX E



MEAN MAX. – MEAN MIN. TEMPERATURE, RELATIVE HUMIDITY AT 0900 HRS AND RAINFALL IN ACCRA SEPT. 1980 - AUGUST 1981(Refer to App B)