KENYATTA UNIVERSITY, NAIROBI, KENYA

A STUDY ON THE BIOLOGY AND THE IMPACT OF NATURAL ENEMIES ON THE AFRICAN WILD SILK MOTH, *GONOMETA* SP. AT KAMAGUTI, UASIN GISHU DISTRICT, KENYA

By

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DECLARATION BY CANDIDATE

This thesis is my original work and has not been presented for a degree in any other University

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DEDICACTION

This thesis is dedicated to my entire family especially my parents, my brothers and sisters for their perseverance, their love and understanding which made this task possible.

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ABSTRACT

The steadily growing demand for silk in all silk consuming countries provides excellent opportunities for any country to venture into wild silk production. In East Africa, 58 wild silk moth species have been found to occur in three lepidopteran families: Saturniidae, Lasiocampidae and Thaumetopoeidae. In Uasin Gishu district, *Gonometa* sp. (Lasiocampidae) would be ideal for generation of supplementary income to resource-poor farmers, reduce host plant destruction, promote conservation of the silk moths and at the same time permit positive utilization of these biological resources by the local community.

Experiments on the population dynamics of *Gonometa* species were carried out at Uasin Gishu district using two Acacia plant species (*Acacia mearnsii* and *Acacia hockii*). Partial life tables were constructed to evaluate the impact of natural enemies on the population of the *Gonometa* species.

Gonometa sp. caterpillars were found feeding on two abundant host plants namely *Acacia mearnsii* (Thornless) and *Acacia hockii* (Thorned). The *A. mearnsii* maintains green forage throughout the year unlike the *A. hockii*, which sheds leaves during a dry spell. Thus *A. mearnsii* could be recommended for mass wild silk cocoon production.

The moth's oviposition was bimodal for a year. The moths start emerging during the months of September-October and the life cycle is completed by moths emerging again during the months of March-April. Moths opted laying eggs on two protected

environments (Net sleeves and Plastic containers). The incubation period in the two environments was significantly different at $p<0.05$ with the plastic containers environment having the shortest period.

Larvae had six developmental instars and the larval period was significantly different ($P<0.05$) between the host plants with the larvae reared on *A. mearnsii* having the shortest developmental period (72.75 ± 1.83 days).

The *Gonometa* sp., cocoon size and weight varied within the sexes. The female cocoons were larger than the male cocoons with the cocoons mean length and mean width being significantly different at $P<0.0001$ within the sexes. The pupa had a diapause period in December-February and June- September. Male larvae spun earlier than the female larvae but all moths emerged almost at the same time and mate.

The sexual dimorphism exhibited in both pupal and adult stages can be used precisely for identification and separation of sexes during the breeding period.

The fecundity of moths kept in the net sleeve environment was higher than that in plastic containers. Eggs in plastic containers had the highest infertility percentage (51.65%).

The survival rate observed during the developmental period of *Gonometa* sp. larvae in this study was higher in the protected than in the unprotected larvae.

Disappearance was the key mortality factor. Disappearance covered combined mortality factors that could not be singled out easily especially predators (Birds), escape of the larvae through the net pores and wondering movements of the released larvae.

CHAPTER ONE

1.0 GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Silk moths grown in wild conditions are known as wild silk moths. In Africa, most of the wild silk moths belong to Saturniidae, Lasiocampidae, and Thaumetopoeidae families. Wild silk production is an eco-friendly, agro- based venture with a great potential for environmental amelioration, employment generation, artisan's development and export earning (Kioko *et al.*, 1999). The potential of the African indigenous species for wild silk production has been documented in Uganda (Gowdey, 1953), Nigeria (Ashiru, 1988), Botswana (Hartland-rowe, 1992) and Zimbabwe (Chikwenhere, 1992). Earlier, Schultze (1914) had noted that the African species of silk moths give strong silk of commercial value. The population of wild silk moths in Africa is declining due to deforestation and the over consumption of silk moth larvae, which are favoured by some communities for food (Ashiru, 1988; Munthali and Mughogho, 1992; Oberprieler, 1994). Recent survey on the diversity of wild silk moths in East Africa by Kioko *et al.* (2000), recorded about 33 species in 17 genera in Lasiocampidae family. Karanja and Chege (1985) in their annotated list of forest insects of Kenya, mentioned some of the host plants of *Gonometa* sp. as *Acrocarpus fraxinifelius, Cupressus forbesii, Cupressus lusitanica, Cupress* sp., and *Pinus patula*. They also reported distribution of *Gonometa* sp. in Muguga, Kakamega, Nairobi, Nakuru and Nyeri.

Caterpillars of *Gonometa* sp. also feed on different species of acacia plants and other plants like podo and *Cupressus* trees (Kioko, 1998). They spin brown cocoons within 50-60 days. Female cocoons are usually bigger and heavier than male ones. About 2,326 female cocoons are needed to produce one kilogram of raw silk, while for the male cocoons about twice the number is required.

Generally, *Gonometa* species are difficult or impossible to rear artificially. Attempts made to rear *Gonometa rufobrunnea* Aurivillius (Hartland-rowe, 1992) in Botswana were unfruitful. Host plant seedling with healthy cocoons have been moderately successful as a means of establishing populations of *Gonometa* in places where they are absent or present only at very low densities (Hartland-rowe, 1992). Methods of using seeding at every developmental stage have been investigated with varying degrees of success. *Gonometa* species exhibit potential for wild silk production but very little is known about them (Chikwenhere, 1992; Hartland-rowe, 1992).

Recent research by Kioko (1998) has shown *Gonometa* sp. cocoons to have good characteristics for wild silk production. The females have high fecundity laying 300-450 eggs and have two broods in a year in East Africa. However, there are some constraints facing the production of *Gonometa* silk. These include lack of sufficient population in the wild, lack of know how on silk farming practices and natural disasters (predators and parasites). To curb some of these problems, different approaches on rearing were investigated to enhance the survival of wild silk worms. These included the protection of the early instars with fine nets in the field and indoor egg production.

1. 2. Literature review

1.2.1. Scope of wild sericulture

Natural silk is broadly classified as mulberry and wild or non–mulberry. Non-mulberry sericulture is universally known as forest or wild sericulture. Tropical and temperate tasar, eri, muga and anaphe are the principal non-mulberry silk. The others include – fagara, coan, mussel, spider and G*onometa* silk (Jolly *et al.*, 1979).

Despite the best efforts of various National and International Agencies, raw silk production has failed to keep up with the steadily rising demand. According to Jolly *et al.* (1979) survey which showed a minimum of 5% annual increase in demand, it would be necessary to expand non-mulberry silk production by 20,000 metric tons over ten years. Some of the leading mulberry silk producing countries appear to have reached saturation point – attributable to the acute scarcity of labour and the increasing cost of production. There is an opportunity for the developing countries to contribute 20,000-28,000 metric tons of raw silk annually for the developed world market. For this reason, the high quality untapped non-mulberry silks, has drawn the attention of silk users (Jolly *et al.*, 1979).

1.2.2.Forest and non-mulberry sericulture

Forests not only constitute the basic means of livelihood of millions of people but also serve for example, to regulate precipitation, conserve soil fertility and reduce erosion. Continuous deforestation of forests since the nineteenth century to meet the industrial demands, the wood trade is consequently a matter of grave concern. Jolly's *et al.* (1979) survey estimated that nearly 10 million hectares of the world's tropical forests is

destroyed every year. There is danger that the short-term benefit may override disadvantages, especially to the indigenous regional forest populations.

Non-mulberry sericulture holds great promise for the world forestry as a supplementary activity. On one hand it can help arrest forest destruction, and on the other hand it permits gainful utilization of this vast natural wealth.

In Uasin Gishu, forests cover 10% of the district's land area. The *Acacia* trees from these forests are used for both industrial and domestic purposes. Locally, the trees are used mainly for fencing, fuel wood and construction (District development plan 1997-2001). Wild silk farming has not yet been introduced in the District.

1.2.3 *Gonometa* silk

Cocoons of *Gonometa postica* Walker (Lasiocampidae) have been reported to occur on the African savanna where larvae feed on the mopane tree, *Colophospermum mopane* Kirk ex j. Leo (Caesalpiniaceae) a resiniferous tree (Hartland- rowe, 1992). Cocoons are collected in the field and give silk of a soft texture and beige colour (Peigler, 1993). In Botswana, a study by Hartland-Rowe (1992) indicated that collecting and processing of this silk can offer a viable source of employment and income to people in the villages. In Zimbabwe, Chikwenhere (1992) reported that from 1986 to 1987, 430 tons of wild cocoons were collected by rural families and this became a source of employment in the rural areas.

In the high plateaus of central Madagascar, *Borocera cajani* Vinson (Lasiocampidae) and allied species occur and these moths are closely related to the *Gonometa* species on the mainland Africa. These have been utilized for silk production by the Belsiles and Mering tribes (Peigler, 1993). The caterpillars feed on resiniferous plants including *Cajanus indicus* Spreng (Leguminosae), *Dononaea madascariensis* Radlk. (Sapindaceae),*Uapaca bojeri* Bail. (Euphorbiaceae) and mango *Mangifera indica* L. (Anacardiaceae). It is recorded that indeed there is a factory of this silk in operation in Madagascar (Peigler, 1993). In Kenya wild silk industries are yet to be established. Survey and research on wild silk farming is going on backed by the Commercial Insects Programme at I.C.I.P.E.

1.2.4 Diversity of the African wild silk moth

The highest diversity of the African wild silk moth is in the family Lasiocampidae. Recent survey in East Africa recorded about 33 species in 17 genera (Kioko *et al.*, 2000). Despite this high diversity, only a few of these species have so far been utilized for wild silk production in Africa. The *Gonometa* species occurring on the African savanna have been commercially harvested in Botswana (Hartland–Rowe, 1992) and Zimbabwe (Chikwenhere, 1992). The close relaitves of *Gonometa, Borocera cajani* Vinson have been used for centuries for wild silk production in the plateaus of Madagascar (Peigler, 1993).

The *Gonometa* larvae have urticating spines and are found feeding on different *Acacia* species, Podo trees in East Africa and on the mopane tree in Sourthern Africa. *Gonometa* cocoons are fixed to twigs along the side by a silk band. Larval spines are incorporated

onto the cocoon when it is being constructed. Akai and Nagashima (1997) detected needle like bristles 2-3 mm along all over the cocoon surface and concluded that they may be useful for protecting the cocoon against enemies such as birds and other vertebrates. Recent studies by Kioko (1998) showed that *Gonometa* sp. occur in Mwingi district, Sultan Hamud in Makueni district, the host plants being *Acacia elaitor* and *Acacia senegal*. Unidentified *Gonometa* species was also found to occur in Kamaguti in Uasin Gishu district; the host plants being indigenous *Acacia hockii* and exotic wattle tree (*Acacia mearnsii).*

1.2.5 Biology of silk moths

Silk moths have four developmental stages (holometabolic) namely: Egg or ovum (the embryonic stage), the caterpillar or larva (the principal feeding and growing stage), the chrysalis stage or pupa (a transition stage) and the adult or imago (the principal dispersive and the sole reproductive stage). Silk moths spin silken cocoons in which they pupate.

The silk contains proteins, which are produced by modified salivary glands in the mouth of the larva and is spun from a special spinneret in the floor of the mouth (Akai *et al.*, 1988; Akai, 1998, Akai and Nagashima, 1999).

The silk filament is a mixture of fibroin or silk proper produced in the silk gland and sericin or silk gum produced in the stomach. Hartland-Rowe (1992) in Northern Botswana, has outlined the life cycle of *Gonometa rufobrunnea* Aurivillus feeding on mopane. The study by Kioko (1998) on *Gonometa* sp. at Nguni, Mwingi district, Kenya, showed that these silk moths have two generations each year. The emergence of adult moth synchronized with the host plant state, which was also influenced by weather

conditions. The studies indicated that pupal stage undergoes diapause, which can be shortened for the continuous cycle of the silk moth generation depending on the food plant state. Kioko (1998) observed that cocoons kept in an incubator with controlled temperatures had a significantly shorter pupal life span than those observed in room conditions.

1.2.6 Population dynamics of *Gonometa* species

Although a female moth lays more than 200 eggs (*Gonometa* 300-450), the population does not continually expand but fluctuates. This is because there are many mortality factors at work throughout the life cycle, all of them varying in time and space. Some of these factors are biotic (parasites and predators) but may also include bacterial and virus diseases as well as the availability of food. Other factors are abiotic and these are mostly climatic. Biotic factors often operate in a density dependent manner (their impact varies with the population density) while the impact of abiotic factors is density independent.

Climatic factors play an important role in regulating the population density of this species. Not only do they directly regulate the timing of the moth emergence and the induction and termination of diapause but they also have great indirect impact by regulating the timing of the availability of food (Hartland–rowe, 1992).

The impact of parasitoids and predators on the larval stage is often far more severe than that of climatic factors. Hartland–rowe (1992) reported 50% egg loss by *Chalcidoid* wasps of three species: *Pediobius anastati* (Crawford), *Mesocomys pulchriceps* Cameron and *Anastatus bifasciatus* Fonscolombre.

There are also larval parasitoids, which lay eggs on the developing larvae and on hatching they live inside the moth's caterpillar. These parasitiods include two species of *Tachinid* flies (*Pimelimyia semitestacea* and *Palexorista* species), and at least four *Chalcidoid* wasps species . *Eurytomid* species and *Eurytoma transvaalensis* are the most abundant parasitoid species. Others are *Tineobius gonometa* (Ferriere), *Hockeria* spp and *Bracthymeria* species. Hartland-rowe (1992) also showed that up to 70% predacious insects eat *Gonometa rufobrunea* larvae. These predators included Reduviid bugs *Callilestes gracilis* Miller and *Cosmolestes pictus* Klug. He also suspected predation from three species of birds, two roller species *Corcacias caudata,* and *C. garrulus* and one hornbill species *Tockus erythrorhynchus.* Cocoons were also reported to have been attacked by predators. Two species so far have been identified, namely the Multimammate mouse (*Mastomys natalensis*) and the squirrel *(Parazerus cepapi).* Other vertebrates suspected to prey on cocoons included monitor lizards and crows. Kioko (1998) reported Hemiptera, Orthoptera, and Hymenoptera as the three insect orders, which prey on G*onometa* species. Adequate information on the natural enemies of the different species of silk moth occurring in East Africa, which is lacking was investigated.

1.2.7 Life Tables

A life table gives systematic account of the magnitude of the various mortality factors acting on specific age groups within a given population. Life tables provide vital basic information required for a better understanding of the population's dynamics of an insect species (Southwood, 1978), and also for the identification of the most appropriate periods

for the implementation of maximum insect pest control (Watt, 1964; Morris, 1963). The first detailed life table for a natural population of an insect (the spruce budworm) was described by Morris and Miller (1954). Since then life tables have been constructed for various insect populations (Prince, 1975)), and many workers follow the format proposed by Harcourt (1969). There are two categories of life tables: i) Horizontal or Age- specific life tables. This type of life table, which is mainly used for insect with definite generations and dynamic age distributions, describes survival of a cohort of individuals, as they age, within a single generation. ii) Vertical or time- specific tables. This category of life tables, which is mainly used for insect with overlapping generations and a stable age distributions, tabulates the survival of an imaginary cohort, by determining the age structure of a random sample of individuals from the populations at a point in time (Southwood, 1978).

Construction of life tables requires estimation of the population densities of several life stages. The number of individuals that enter a particular stage in each generation is determined from successive samples of the populations, and then analyzed using statistical methods (Southwood, 1978).

1.2.8 Key factor analysis

Key factor analysis uses a series of life table of several generations of the same population to identify the mortality factor most likely responsible for the observed changes in population's density (the key-factor) (Morris, 1959) under the current conditions. It is not necessarily responsible for maintaining the typical density of the host

populations. The "Killing power' (k-values) of each of the individual mortality factors, is the difference between the logarithms of the populations density before and after the mortality acts on the population.

Thus, K-value-= Log N_1- Log N_2.

Where N_1= population density before mortality.

N_2= Population density after mortality

Since the series of age-specific mortalities (k-values) are assumed to act in sequence, the sum of k-values equals the total generational mortality (K) (Varley and Gradwell, 1968).

Thus, $K=k_1 + k_2 + k_3 + ...$

The graphical methods of key factor analysis (Varley and Gradwell, 1960) involves plotting the total generational mortality (K) and each of its components (k_1, k_2, k_3) representing mortalities occurring in successive life tables, against generational number. The key factor is the one whose change is most closely correlated with the change in the total K. (through visual observation) (Southwood, 1978).

However, there may be cases where none of the factors appears to be clearly correlated more than the others with the change in total K. In such cases, another method (analytical method) developed by Podoler and Rogers (1975) is proposed. The analytical method of key-factor analysis based on a regression of k_1, k_2, k_3...against total K. The k-value with the highest regression co-efficient (slope) is the key factor. The closer the slope is to 1, the more the specific mortality factor contributes to the total variation in K. The relative

effect of each of the other mortality factors can also be determined by comparing the values of their slopes.

1.3 JUSTIFICTION OF THE STUDY

The genus *Gonometa* is one of the representative silk spinning insects on the African continent, belonging to the Lasiocampidae family. The steadily growing demand for silk in all silk consuming countries provides excellent opportunities for any country to venture into wild silk production.

The introduction of wild silk production in Uasin Gishu may offer an important economic incentive to farmers in the District. With the economic hardships faced by the local community, *Gonometa* silk production may offer a supplementary income generating activity. Community awareness and the abundance of the host trees (*Acacia mearnsii* and *Acacia hockii*) will promote initiation of silk production in the District. Since the community is aware of the existence of the *Gonometa* sp., the enterprise will enhance the community to understand the importance of the *Gonometa* species. This enterprise will also enhance the conservation of the wild silk moth, *Gonometa* species and their habitats for silk production. The final resultant goal will be conservation and utilization of bio-diversity.

The reduction in the species composition and natural population density of the wild silk moths may be due to change in the ecosystem/climate/environment/ biotic factors viz. depletion of the plants caused by extensive deforestation. The ever increasing human population density has created pressure on land use, resulting in human colonization in

the forest land for human dwelling and cultivation which has greatly changed the biotic components viz. fauna and flora. The other reasons for depletion of these wild silk moths may be their restricted level of distribution, narrow range of food plant preference (Oligophagy), low survival rate, increasing attack by natural enemies viz. parasites, predators and diseases. This calls for an urgent need for conservation of these sericigenous insects, which are ecologically important. In Kenya, wild silk worms have not been commercially exploited. Consequently their ecological role is not well known. Hence there is need to study the bio-ecology of wild silk moths.

1.4 HYPOTHESES

1. Understanding growth and development of *Gonometa* sp. moths and the mortality factors can enhance silkworm cocoon production.
2. The production of silkworm cocoons is low due to the high mortality rate caused by natural enemies of young larvae and eggs.
3. There is a significant difference in the survival of the protected and unprotected silk worms.

1.5 OBJECTIVES

1.5.1 General objective

To study the life cycle and evaluate the impact of natural enemies on *Gonometa* sp. population growth and development.

1.5.2 Specific objectives

1. To study the life cycle of *Gonometa* species.
2. To evaluate the role of parasitoids and predators in the regulation of *Gonometa* species populations through the construction of life tables.
3. To study the effect of protecting early developmental stages of *Gonometa* sp. on its population growth.

CHAPTER TWO

2.0 GENERAL MATERIALS AND METHODS

2.1 Study site

The study on the population trends of wild silk moth *Gonometa* species was carried out in Uasin Gishu District (Figure 2.1) in Kenya (Figure 2.2). The District extends between Longitudes 34° 50' and 35° 37' East and 0° 03' and 0° 55' North. Its terrain varies greatly with altitude, which ranges between 1,500-2,100 meters above sea level. Eldoret town at an altitude of 2,085 meters marks the boundary between the highest and the lowest altitudes of the district. Rainfall is bimodal and occurs between the months of March and September with two peaks in May and August (District Development plan 1997-2001). Two Acacia tree species namely; *Acacia hockii* and *Acacia mearnsii* that occur in this area were used in these studies.

Figure 2.1 Map of Uasin Gishu District showing Kamaguti area

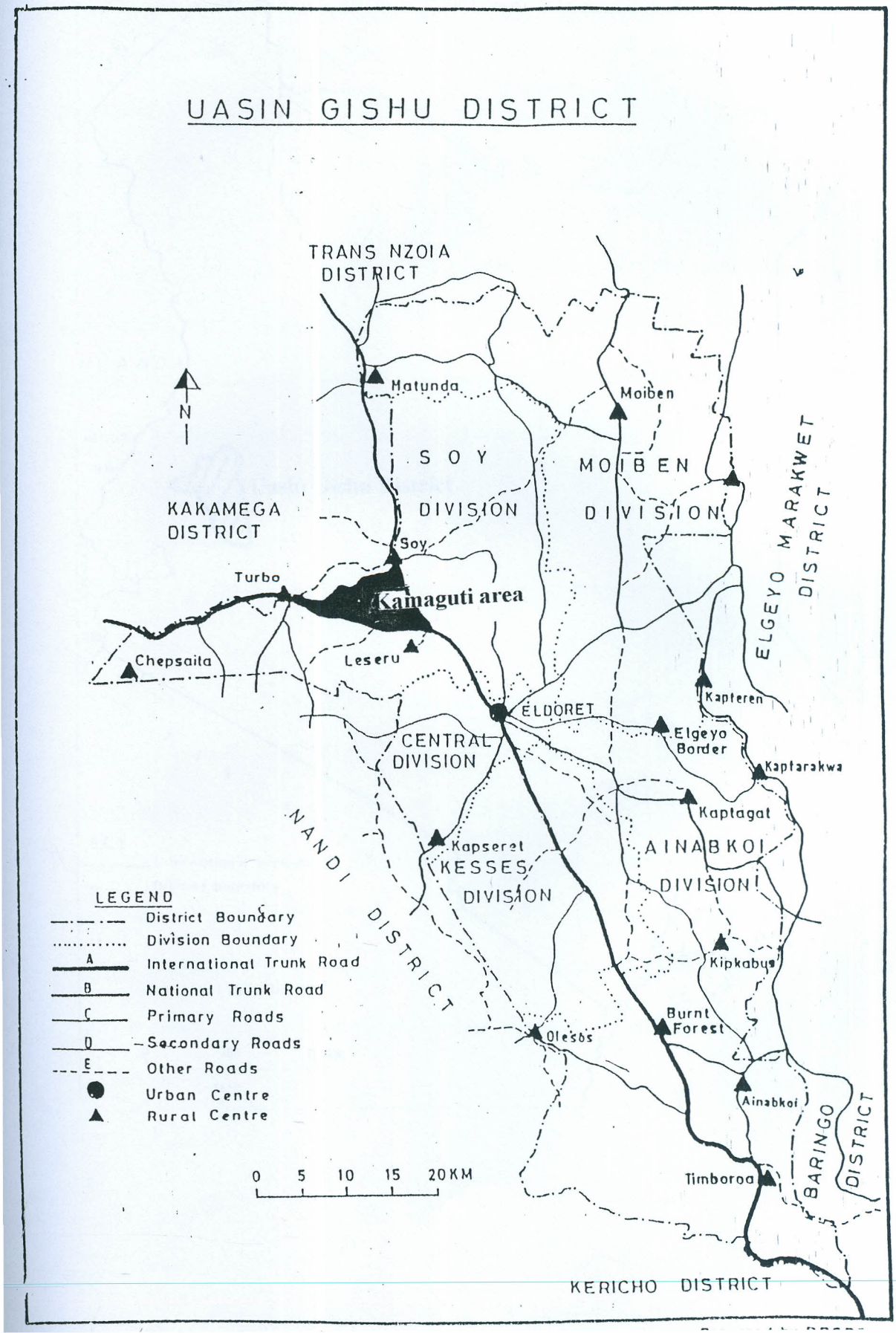
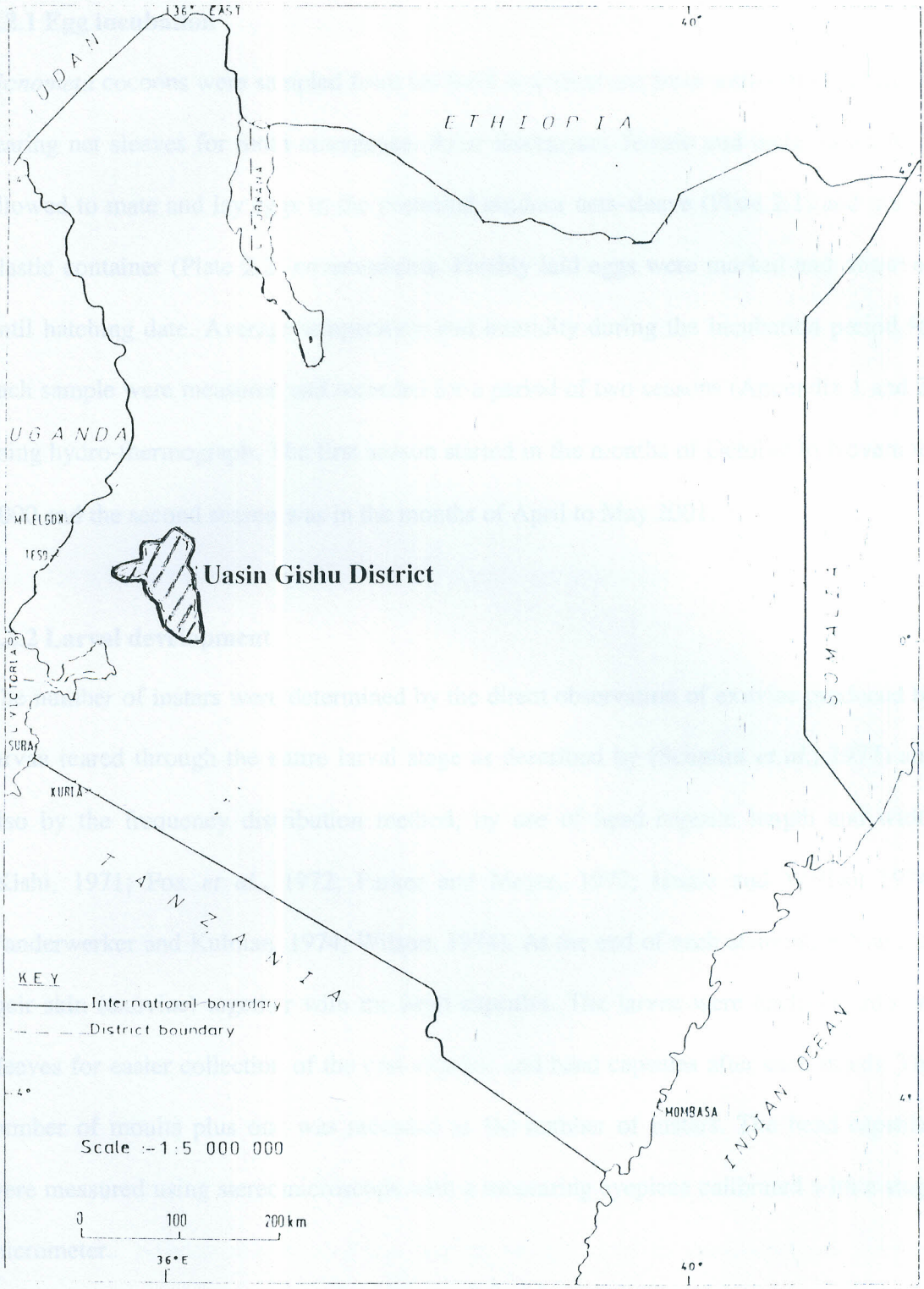


Figure 2.2 Map of Kenya showing the location of Uasin Gishu District



2.2 Life cycle of *Gonometa* species

2.2.1 Egg incubation

Gonometa cocoons were sampled from the field and observed from well-ventilated insect rearing net sleeves for moth emergence. After emergence, female and male moths were allowed to mate and lay eggs in the protected outdoor nets-sleeve (Plate 2.1) and indoor plastic container (Plate 2.2) environments. Freshly laid eggs were marked and observed until hatching date. Average temperature and humidity during the incubation period for each sample were measured and recorded for a period of two seasons (Appendix 1 and 2) using hydro-thermograph. The first season started in the months of October to November 2000 and the second season was in the months of April to May 2001.

2.2.2 Larval development

The number of instars were determined by the direct observation of exuviae produced by larvae reared through the entire larval stage as described by (Schmint *et al.*, 1977) and also by the frequency distribution method, by use of head capsule length and width (Kishi, 1971; Fox *et al.*, 1972; Parker and Meyer, 1972; Hoxie and Wellso, 1974; Vanderwerker and Kulman, 1974; Wilson, 1974). At the end of each stadium, larvae cast their skin (exuviae) together with the head capsules. The larvae were enclosed into net sleeves for easier collection of the cast exuviae and head capsules after each moult. The number of moults plus one was recorded as the number of instars. The head capsules were measured using stereomicroscope with a measuring eyepiece calibrated with a stage micrometer.

2.2.3 Pupal period

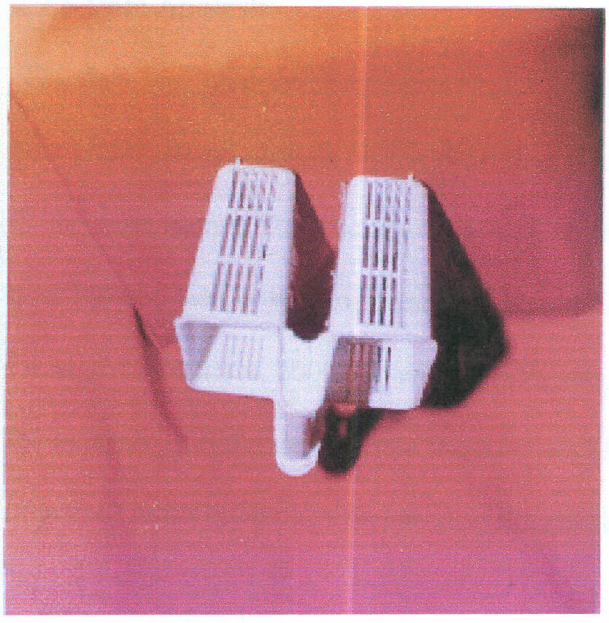
The pupal period was determined by marking cocoons at the date of spinning and observing them until the date the moths emerged. The cocoons were marked with permanent marker pens, which were resistant to effects of water. The marked cocoons were kept under room temperature and observed till moth emergence. Cocoon size and weight was used to separate sexes in pupal stage. This also helped to determine the *Gonometa* sp. sex in adult stage by measuring the moth's wing length after emerging from the cocoons. The interval between the date of spinning and emerging time was recorded as the pupal period. Thirty-five observations were considered for data analysis. This was done in two seasons in a period of one year. The pupal period for sexes was recorded and their means compared for any significant difference.

2.2.4 Adult fecundity and fertility

Fertility is explained as the number of viable eggs produced by a female, while fecundity is a measure of the total egg production (Southwood, 1968). According to Klomp (1966), fecundity represents the number of eggs deposited plus the mature eggs present in the oviduct after death. To determine female reproduction, pairs of freshly emerged female and male moths were isolated from the breeding cage and enclosed in net sleeves (Plate 2.1) and other pairs were placed in plastic containers (Plate 2.2) for mating and oviposition. Thirty-five (35) replications of paired moths were used in each set-up. The total complement of eggs produced by females was determined from the mated caged females and subsequently adding the number of eggs laid to those obtained through dissection from the dead females.

Plate 2.1. Net sleeve used for egg laying and incubation set-ups

Plate 2.2. Plastic container used for egg laying and incubation set-ups



2.2.5 Determination of natural enemies and effect of mortality factors

In order to develop a sustainable mass production of *Gonometa* sp. cocoons it would be necessary to identify, evaluate and compare the impact of natural enemies on it's developmental stages. The natural enemies of egg, larval and adult stages were determined by visual observations at the incubating, rearing and breeding sites respectively. The natural enemies of the pupal stage were determined by enclosing the cocoons in well-ventilated cages. Parasitoids emerging from the cocoons were collected for identification. A sample size of thirty-five fresh spun cocoons was used to estimate the percentage of cocoon parasitism.

One of the commonly used methods, in the evaluation of the impact of natural enemies, is life table analysis (Bellows *et al*, 1992). Partial ecological life tables were constructed following a format proposed by Harcourt (1969).

2.2.6 Data Analysis

The data was analyzed according to seasons and sex. Since larvae were reared on two host plants; *Acacia hockii* and *Acacia mearnsii,* only larval stage was analyzed according to the host plants. Data comparison between seasons and sexes was done (and where possible between host plants) using independent T-test and Analysis of variance (PROC GLM, SAS institute, 2000). In each experiment, thirty -five observations were considered for analysis. Key-factor analysis (Podoler and Rogers, 1975) was used to determine the impact of mortality factors on larval and pupal developmental stages.

CHAPTER THREE

3.0 THE LIFE CYCLE OF *GONOMETA* SP. REARED ON *ACACIA MEARNSII* AND *ACACIA HOCKII*

3.1 INTDODUCTION

Gonometa species undergoes holometapholous metarmorphosis and has four developmental stages namely: egg or ovum (the embryonic stage), the caterpillar or larva (the principal feeding and growing stage), the chrysalis stage or pupa (a transition stage) and the adult or imago (the principal dispersive and the sole reproductive stage). According to Kioko (1998) at Mwingi District, *Gonometa* sp. feeds on a wide range of *Acacia* species and has two seasons in a year, the first season occurs between the months of March and September while the second season begins in October and ends in March. *Gonometa* sp. lays eggs in various substrates.

3.2 MATERIALS AND METHODS

The initial population for the experiment was set up by collecting live *Gonometa* sp. larvae and cocoons to prepare the breeding stock. The prepared *Gonometa* cocoons were enclosed in a 2m x 2m x 2m net- sleeved cages (Plate 3.1). Only fresh healthy female and male cocoons were selected for moth's emergence. Two various substrates were utilized to test fertility and fecundity of *Gonometa* species: net sleeves and plastic containers, each in a different environment. The net sleeves were exposed into an outdoor environment and the plastic containers were kept indoors to determine a favorable environment for egg laying and incubation period.

Plate 3.1. Net cage used for mass breeding

To determine female reproduction, pairs of freshly emerged female and male moths were isolated from the breeding cage and enclosed in net sleeves and other pairs were placed in plastic containers for mating and oviposition. Thirty-five (35) replications of paired moths were used in each set-up. The average humidity and temperature were measured and recorded daily using hydro-thermograph. The life span of the females was recorded and the total number of eggs laid recorded. Eggs laid on daily basis were marked to determine the incubation period in both set-ups. The total complement of eggs produced by a female was determined by adding the number of eggs laid by the caged female to those obtained through dissection from the dead female. The dead females were preserved in 70% alcohol for at most a month before dissection under microscope. The life span of male moths was also recorded for comparison with that of the female moths.

The larval period was determined by rearing the *Gonometa* sp. larva on the *Acacia mearnsii* and the *Acacia hockii* until they spinned. This was necessary in order to identify the host plant that could be recommended for wild silk cocoon production in Uasin Gishu distict. The rearing was done by protecting the entire larval stage with net-sleeves (Plate 2.1). The net sleeves had a capacity of holding fifty worms at their final instars. To determine the number of instars by visual observation of exuviae (Schmidt *et al.*, 1977) and by use of head capsule length and width (Kishi, 1971; Fox *et al.*, 1972; Parker and Meyer, 1972; Hoxie and Wellso, 1974; Vanderwerker and Kulman, 1974; Wilson, 1974), ten net sleeve replicates were set up in each host plant field site. Each replicate had ten worms making a sample size of one hundred worms per host plant. These replicates were also used to identify the possible mortality factors within the larval stage.

To determine pupal period, the cocoons were marked, harvested and kept in an enclosed net–sleeve till moths emerged. The harvesting was done seven days after pupation for the cocoon to dry up and give the larvae time to change into pupae. The cocoons were collected in the months of December 2000, January and February 2001, for the first season and in the months of June, July and August 2001, for the second season.The data was analyzed using analysis of variance (PROC GLM, SAS institute, 2000) and independent T-test for significant difference between means at 0.05% confidential level.

3.3 RESULTS

3.3.1 EGG INCUBATION PERIOD

The moths' oviposition was bimodal for a year. The first *Gonometa* sp. oviposition season was observed in the months of October and November (Table 3.1). The eggs were laid randomly in clusters in various substrates. The plastic containers and net sleeve egg incubation means were significantly different at $p < 0.05$ with the plastic containers environment having the shortest period. There was no significant difference for the net sleeve environment within seasons but there was a significant difference for plastic containers environment at $p < 0.05$ within the two seasons (Table 3.1).

The mean incubation period of eggs laid in the indoor plastic containers was 13.67 ± 0.28 days while that of eggs laid in the outdoor net sleeve was 17.77 ± 0.35 days. The second oviposition season was observed in the months of March and April (Table 3.1). The mean incubation period for the indoor incubated plastic container's eggs was 15.03 ± 0.42 days while the mean incubation period for the outdoor net sleeve incubated eggs was 18.41 ± 0.63 days.

There was no statistical significant difference of temperature in the two set-ups but there was a significant difference of temperature within seasons. In the two set-ups, the first season had a higher mean temperature in comparison to a lower mean temperature in the second season. Mean humidity varied significantly both in the two set-ups and within seasons (Table 3.1).

Table 3.1: Egg incubation period of *Gonometa* sp. during the October-November 2000 season (1) and the March-April 2000 season (2) in Uasin Gishu district

Environment	Incubation period (days) Season (1)	Temperature (c^0)	Humidity	Incubation period (days) Season (2)	Temperature (c^0)	Humidity
Plastic containers	13.65± 0.28aA	23.33 ± 0.51aA	64.82 ± 2.7aA	15.03±0.42aB	21.92 ± 0.76aB	64.97 ± 4.03aA
Net sleeves	17.77 ±0.35Ab	23.6 ± 1.07aA	63.38 ±3.63bA	18.41±0.63Ab	21.76 ±1.24aB	67.3 ± 5.75bB

Means followed by the same lower case letters in the same column and upper case letters in the same row are not significantly different (T-test 0.05%)

The column means compare statistical differences within set-ups while row means compares statistical differences within seasons.

3.3.2 LARVAL DEVELOPMENT

The *Gonometa* sp. larvae were observed feeding on the two host plants namely, *Acacia hockii,* which is an indigenous species of the area and on *Acacia mearnsii,* an exotic species. The direct observation of larvae exuviae reared through the entire larval stage showed that five moults occurred from the first instar to the time the larvae pupated, hence six instars. The head capsule measurements confirmed the results through the

gradual growth of width and length (Figure 3.1). The periods spend at each instar by the larvae before moulting is shown in Table 3.2.

Gonometa sp. larvae were gregarious up to the end of the third instar. They showed colour variations in the between first instar and the second instar. The first instar larvae were black with a single white stripe within the thorax section (Plate 3.2). After the first moult to spinning stage, they acquired a mixture of white and black hairs with much longer hairs on the lateral sides. Larvae were also equipped with sharp black and brown spines that are irritating when they pierce ones skin (Plate 3.3).

The larval period mean was significantly different at $P < 0.05$ between the two host plants. The *Acacia hockii* reared larvae took the longest period of 99.15 ± 4.95 days to spin than those reared on *Acacia mearnsii* which took 72.75 ± 1.83 days (Table 3.3).

Table 3. 2: Head capsule measurements of *Gonometa* sp. larvae

Moulting	Age before each moult (Days)	Mean length (mm) ± SE	Mean increment (mm)	Mean width (mm) ± SE	Mean increment (mm)
I	8.4 ± 0.5	1.25 ± 0.01	0	1.2 ± 0.01	0
II	8.9 ± 0.53	1.74 ± 0.11	0.49	1.72 ± 0.1	0.52
III	11.2 ± 0.45	2.67 ± 0.13	0.93	2.56 ± 0.13	0.84
IV	13.7 + 0.76	3.5 ± 0.05	0.83	3.45 ± 0.05	0.81
V	17.9 ± 1.19	4.68 ± 0.12	1.18	4.57 ± 0.11	1.12
Pupa	8.2 ± 2.02	_____	_____	_____	_____

Plate 3.2. First instar *Gonometa* sp. larvae

Plate 3.3. Fifth instar *Gonometa* sp. larvae

Figure 3.1: Mean length and width (mm) of *Gonometa* sp. headcapsules

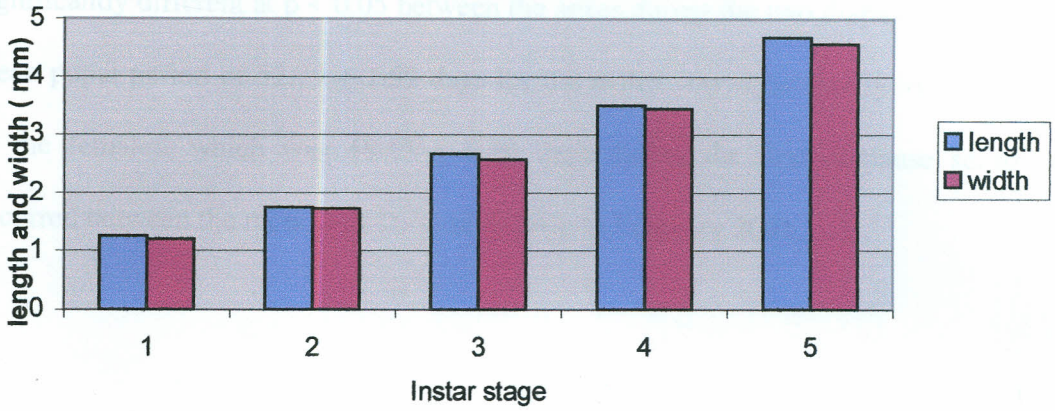


Table 3. 3: Comparison of *Gonometa* sp. mean larval developmental period in two host plants

Host Plant	Larval period (Days)
Acacia mearnsii	72.75 + 1.83a
Acacia Hockii	99.15 + 4.9b

Means followed by the same letters in the same column are not significantly different (T-test 0.05%)

3.3.3 PUPA

The pupal stage of *Gonometa* sp. is enclosed in a tough brown silk cocoon. The cocoon in *Gonometa* sp. is compact, brownish in colour and has irritating spines on the upper surface (Plate 3.4). The cocoon size and weight varied within the sexes. The female cocoons were larger than the male cocoons with cocoons mean length and mean width being significantly different at $p < 0.05$ within the sexes (Table 3.4). The pupal weight was also significantly different at $p < 0.05$ within the sexes. The male cocoons with a mean weight of 2.32 ± 2.21 grams were significantly lighter than the female cocoons with

a mean weight of 5.75 $\pm$ 0.26 grams (Table 3.4). The pupal diapause means were significantly different at $p < 0.05$ between the sexes during the two diapause seasons. The mean pupal period of 52.79 $\pm$ 1.89 days for the males was significantly longer than that of the females, which was 48.43 $\pm$ 0.99 days during the first diapause season that occurred between the months of December 2000 to February 2001.

Plate 3.4 *Gonometa* sp. cocoons

Female cocoons

Male cocoons

The second diapause season occurred between the months of June 2001 to September 2001 with a mean pupal period of 65.15 ± 6.97 and 72.42 ± 4.49 days for males and females respectively (Table 3.5). The second diapause period was statistically longer than that of the first season in within sexes (Table 3.5). Males spun earlier than females but all moths emerged almost at the same time and mated (Figure 3.2 and 3.3). This explains well why males seem to take a longer diapause period than the females in each of the two seasons.

Table 3. 4: Comparison of *Gonometa* sp. mean cocoon weight and size

Variable	Males	Females
Weight	2.32 ± 2.21a	5.75 ± 0.26b
Length	3.42 ± 0.09a	4.36 ± 0.11b
Width	1.13 ± 0.03a	1.53 ± 0.05a

Means followed by same letters in the same row are not significantly different (T-test 0.05%)

Table 3. 5: Comparison of *Gonometa* sp. pupal period within two seasons

Sex	Season 1: December 2000-February 2001 (Days)	Season 2: June-September (2002) (Days)
Female	48.43 ± 0.99aA	65.15 ± 6.98aB
Male	52.79 ± 1.89bA	72.42 ± 4.49bB

Means followed by the same letters in the same column are not significantly different (T-test P<0.05)

Column means compare statistical differences between sexes and row means compares statistical differences between seasons.

Figure3.2: *Gonometa* sp. larvae spinning rate

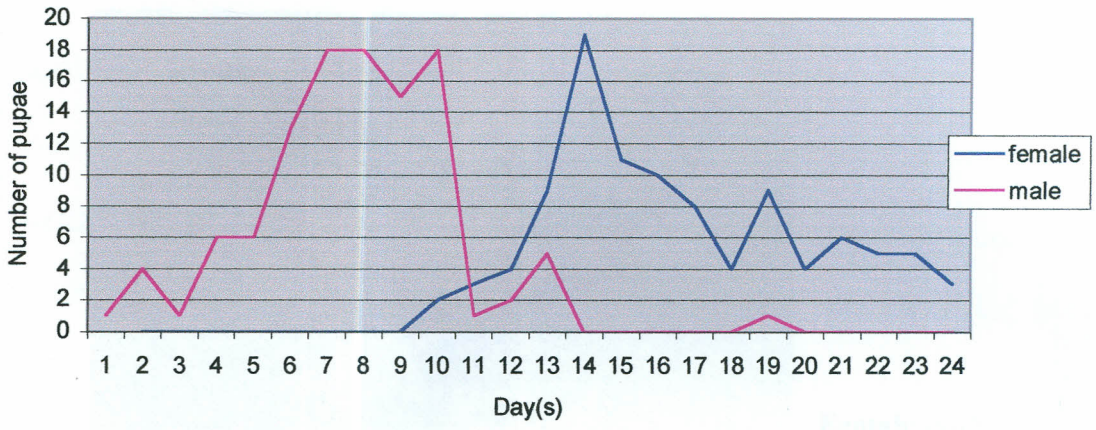
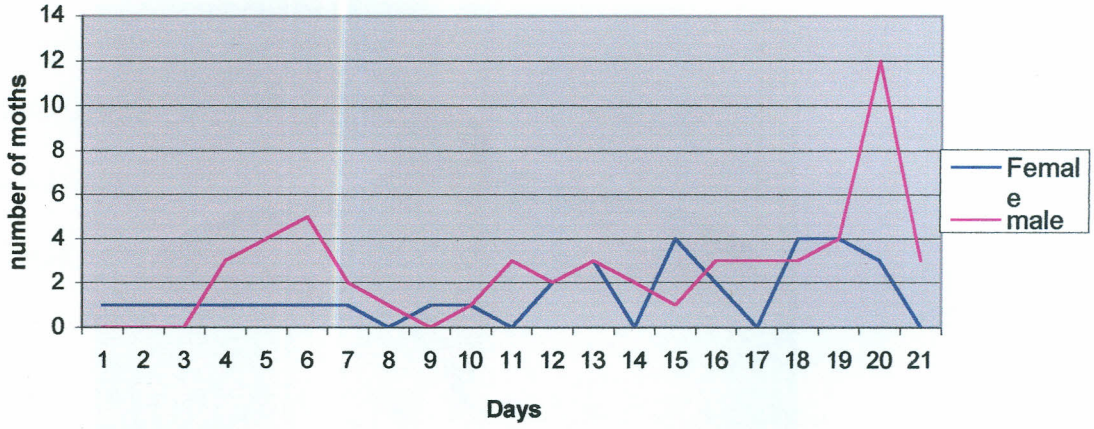


Figure 3.3: *Gonometa* sp. moths emerging sex ratio



3.3.4 ADULT

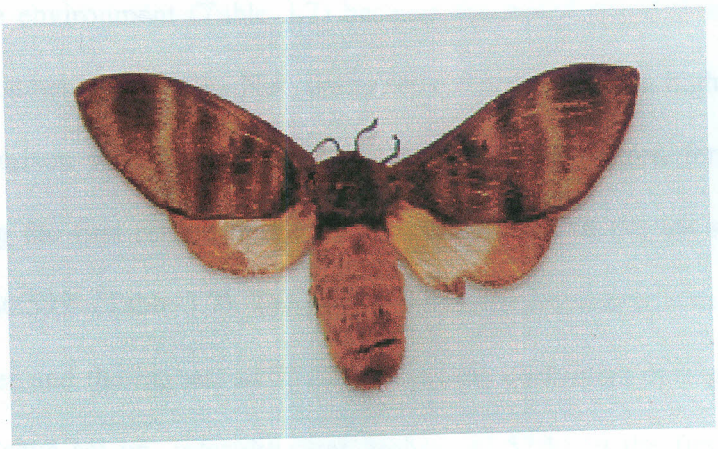
Gonometa sp. showed very distinct sexual dimorphism. The females were larger than the males (Plate 3.5). The females had large mean wing length of 8.93 $\pm$ 0.32cm which was significantly longer ($P < 0.05$) than that of the males (5.04 $\pm$ 0.21cm) (Table 3.6).

Table 3.6: Adult *Gonometa* sp. moth wing length comparison

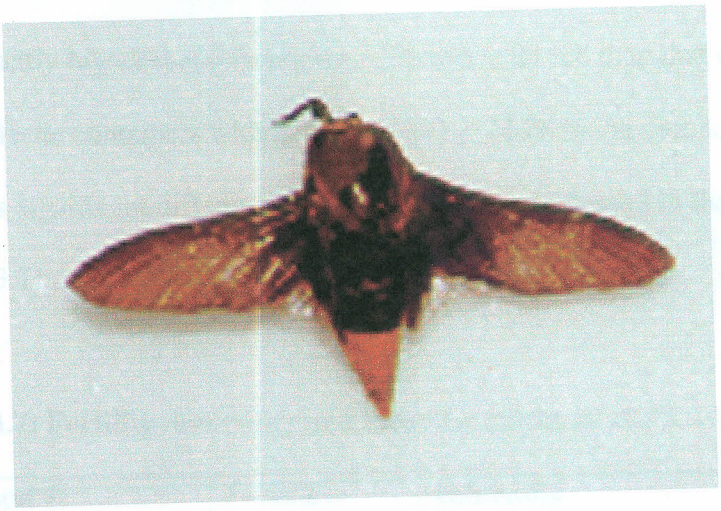
Sex	Female	Male
Wing length	8.93 $\pm$ 0.32cm a	5.04 $\pm$ 0.21cm b

Means followed by the same letters in the same row are not significantly different (T-test $P<0.05$)

Plate 3.5. Adult *Gonometa* sp. moths



Female moth



Male moth

The fertility, infertility and mean fecundity results for the first season shows only the net sleeve environment (Table 3.7) because the initial population was too low for the two environmental set-ups. Net sleeve environment had a higher fertility of 80.59% in comparison with 48.35% in plastic containers. However, fertility was lower (52.43%) during the first season than in the second season in the net sleeve environment, which was 80.59% (Table 3.7). The lowest infertility percentage was recorded as 19.41% in net sleeves and the highest as 51.65% in plastic containers during the second season. In the net sleeve set up, infertility was higher (47.57%) in the first season in comparison to 19.41% in the second season (Table 3.7). The female moths kept in the net sleeves had a significantly higher mean fecundity of 338.65 $\pm$ 24 .28 than that of the female moths kept in the plastic containers with a mean of 293 $\pm$ 22.28 in the second season. However, there was less significant difference at $p < 0.05$ in the net sleeves in the first and second season (Table 3.7).

Table 3.7: Fertility, infertility and mean fecundity of the female adult moths

Season 1	**Fertility Percentage**	**Infertility Percentage**	**Mean fecundity:**
Environment (A) Net sleeves	52.43%A	47.57%A	319.34 $\pm$ 22.99A
Season 2			
Environment (A) Net sleeves	80.59%aB	19.41%aB	338.86 $\pm$ 24.28aB
Environment (B) plastic containers	48.35%b	51.65%b	293.65 $\pm$ 22.28b

Means followed by the same letters in the same column are not significantly different (T-test P<0.05)

3.4 DICUSSION

The study has shown that there are two distinct generations of the *Gonometa* wild silk moth species per year at Kamaguti. The two generations coincided well with the on set of long (March-July) and short (October-December) rains, which could be a proper timing for food availability for the young larvae. Having two generations of *Gonometa* species per year is an advantage to the farmers since they can have two harvests of cocoons hence increases in silk production. In Mwingi and Makueni Districts, Kioko (1998) observed two generations per year for *Gonometa* sp.

This study shows that eggs laid and incubated in net sleeves outdoor set-up took a longer period in comparison to that in the plastic containers-indoor set-up (Table 3.1). The statistical differences in the two set-ups could be attributed to temperature and humidity variations evidenced especially between the two seasons. It was noted that temperatures were higher during the first season with shorter egg incubation period recorded in comparison to the second season. The set-up with shorter egg incubation period (plastic containers) would be recommended in grainage (hatchery) system. The incubation period in the plastic containers-indoor environment compares ($13.65 \pm 0.28 - 15.03 \pm 0.42$ days) well with Kioko's (1998) studies at Nguni, Mwingi District which had shown *Gonometa* sp. eggs to have an incubation period of 11.3 ± 0.1 days in an out door environment, but the results do not concur well with those obtained in the net sleeve-out door environment (Table 3.1) at Kamaguti,Uasin Gishu District. The incubation period differences occurring in the different environments and localities could be attributed to fluctuations of temperature and humidity.

The developmental period of larvae at Kamaguti study (0^{o} 55'N, 35^{o} 37'E), took a longer period (Table 3.2) in comparison to previous studies by Kioko (1998) in a different locality. Kioko (1998) at Nguni, Mwingi District (2^{o} 12'S, 38^{o} 16E') had shown *Gonometa* sp. larvae to have a shorter developmental period of 53.5 $\pm$ 6.2 days. This indicates that the prevailing climate of an area has impact on the development of wild silk moths.

Moreover, since the larval stage is the only feeding stage, developmental differences could also result due to the effect of host plants. In this study larvae reared on the indigenous *Acacia hockii* had a longer developmental period in comparison to those reared on the exotic *Acacia mearnsii.* In Kamaguti, *Acacia mearnsii* could be recommended for wild silk rearing because it was noted to maintain green leaves throughout the year. The host plant is also popularly known as a source of nectar and pollen for bees, timber and tannin products; therefore conserving the host plant for wild silk rearing would have a great impact on biodiversity conservation and economy stability of the people in the area.

Observation of exuviae was the most dependable method of determining the number of the *Gonometa* species instars since it was possible to observe the various changes in a stadium very closely until ecdysis occurred. The cast exuviae confirmed moulting between instars making the method an easy application. These observations are in agreement with the reports by Ashiru (1988), who recommended the direct observation method as the most reliable method in determination of *Anaphhe venata* larval instars. The head capsule measurements are useful when the larval stage is not known and such

measurements might not be accurate as an instar determinant method when growth of larvae is not uniform. The method could be a better method to access growth rate of larvae by accessing the increment rate of the length and width of the head capsule between instars (Table 3.2). Fox *et al.* (1972), Schmidt *et al.* (1977) and Ashiru (1988) in their studies found shortcomings in the head capsule frequency method.

There was a variation in the pupa diapause periods during different seasons of the year. The longest diapause occurred between the months of June 2001 to September2001 while the shortest was between the months of December 2000 to February 2001. The pupal period almost took the same mean period with the larval period under the room temperature. The long diapause period coincides well with a cold period (June-July) and a short dry spell (August-September) after the long rains while the short diapause period coincides well with a dry spell after the short rains. These findings do not concur well with Kioko's (1998) report, in Mwingi district, that the pupa diapause period of the *Gonometa* sp. was the longest developmental stage. The differences could be attributed to climate differences brought about by different altitudes considering that Uasin Gishu altitude ranges between 1,500-2,100 meters above sea level and that of Mwingi district is 900-1400 meters above sea level.

The study shows the fecundity of the Gonometa sp. moths to range between 293.65 $\pm$ 22.28 as the lowest and 338.86 $\pm$ 24.28 as the highest depending on the environmental set-up. Thus the set- ups could be manipulated to come up with the highest fecundity and fertility (Table 3.7). The fecundity observed for *Gonometa* sp. concurs well with fecundity for other species currently being utilized for wild silk production. In the *Antheraea paphia* moths, Nayak *et al.* (1994) reported 334.64 $\pm$ 20.51, as maximum egg

production per silk moth and 216.23 $\pm$ 12.67 was the lowest production in his experimental silk moth.

There was variation within sexes in the cocoon size (Table 3.4) and adult moth's wing length (Table 3.6). The sexual dimorphism exhibited in the pupal and adult stage can be used precisely for identification and separation of sexes during breeding period. Previous studies by Kioko (1998) at Nguni, Mwingi district on the *Gonometa* sp. reported statistical difference in the size of male and female cocoons as well as in the adult moths.

CHAPTER FOUR

4.0 NATURAL ENEMIES OF *GONOMETA* SP., AT KAMAGUTI, KENYA

4.1 INTRODUCTION

Insects have their natural enemies and wild silk moths experience economic loss from parasitism than the domestic ones. In order to develop a sustainable *Gonometa* sp. population, it would be necessary to evaluate and compare the impact of the indigenous natural enemies. One of the commonly used methods in the evaluation of the impact of natural enemies is by the life table analysis (Bellows *et al*, 1992). It is important to identify these enemies so that their regulatory effects can be deliberately reduced. In Asia, parasitoids that have been reported to attack wild sericulture are chalcidoid wasps attacking caterpillars (Jolly *et al*., 1979; Thangavelu *et al*., 1988; Peigler, 1989). Studies carried out in U.S.A by Coffelt and Schultz (1992, 1993 a) revealed that new parasitoids records of wild silk moth species still await identification. Kioko (1998) observed *Mesocomys pulchriceps* Cameron (Eupelmidae) and *Pediobus anastati* (Crawford) as egg parasitoids of *Gonometa* sp.

4.2 MATERIALS AND METHODS

4.2.1 Determination of natural enemies

A sample size of thirty-five cocoons was collected from the field and was kept under laboratory conditions to determine the emergence of parasitoids. This method enabled to identify and determine the percentage parasitism of the parasitoids involved. In the cage

experiment, all insects and other anthropods within the vicinity of the silkworms were observed, collected and identified

Other mortality factors were determined by releasing fourth instar larvae on two host plants (*Acacia mearnsii* and *Acacia hockii*). Each host plant had four replicates with a sample size of fifty larvae (50) for each replicate. The replicates were single host plants that had enough forage to host fifty- fourth instar larvae. Counts of the surviving larvae in each host plant were made after seven days. Close observation on the possible causes of mortality was made on daily basis.

4.2.2 Data Analysis

Partial life tables were constructed for two seasons to evaluate and compare the impact of the indigenous natural enemies on *Gonometa* sp. population. Due to low initial population during the first season, only partial life tables for the protected larvae were constructed. During the second season, a mortality comparison through the construction of partial life tables was performed between the protected and unprotected larvae.

Key factor analysis was used to identify the k-values most closely associated with variations in the total generational mortality (K) (Varley and Gradwell, 1960). A k-value, which is the change in number of larvae between each life stage, indicates the level of mortality acting on that stage. The k-value is the logarithm of the difference of the population size between stages. The k-values are preferred over percent mortality because as logarithms, the k-values from each stage are additive over the life cycle to give the logarithm of the generational mortality, K. Due to the many mortality factors and the few numbers of generations, Podoler and Rogers (1975) method of key factor analysis was also used in order to ascertain results from the graphical approach by Varley and

Gradwell (1960). The k-values were regressed against the total K (Podoler and Roger, 1975). The factor with the highest significant slope is the key factor.

4.3 RESULTS

4.3.1 Natural enemies identification

Since egg production was done in two protected environments (Net sleeve and plastic containers environment), no egg parasitism was evidenced during this study.

Macrorphaphis spurcata (A.walker) was observed crawling on the net sleeves with *Gonometa* larvae, probably attempting to attack the caterpillars. Formicidae ants, *Camponotus* sp. (carpenter ants) predated both the larvae and the adult moths. Birds posed a great threat to larval survival especially on the released larvae. The birds identified included black-headed oriole O*riolus larvatus rolleti*, Common fiscal *Lanius collaris humeralis* and crowned Hornbill *Tockus alboterminatus geloensis.* The birds mostly attacked the fourth and the fifth larval instars as they were big enough to be seen. The birds tore through the protecting net sleeves to get the larvae. It was observed that, *Gonometa* sp. larvae develop protective spines during the 4^{th} instar stage in addition to camouflage colour that almost resembles the bark of their host plants and this served as a protective mechanism against the natural enemies. Other parasitoids identified were *Compilura* sp. (Tachnidae), *Coccygomimus* sp. (Icheumonidae) that emerged from *Gonometa* sp. cocoons. A summary of qualitative *Gonometa* sp. natural enemies collected in the experiment field for identification is shown in table 4.1. Plate 4.1 shows unidentified parasitoid cocoon shells on a developing larva.

Plate 4.1. *Gonometa* sp. larvae with parasitoid cocoons

Table 4.1. Quantitative summary of the *Gonometa* sp. natural enemies collected for identification

Identification	Category	Life stage affected	Sample size for identification
Macrorphaphis spurcata (Pentamidae)	Predator	Larvae	10
Camponotus sp. (Formicidae)	Predator	Larvae and moths	10
Oriolus larvatus rolleti (Bird)	Predator	Larvae	4
Lanius collaris humerali (Bird)	Predator	Larvae	3
Tockus alboterminatus geloensis. (Bird)	Predator	Larvae	5
Compilura sp. (Tachnidae)	Parasitoid	Pupa	10
Coccygomimus sp. (Icheumonidae)	Parasitoid	Pupa	10

4.3.2 Life Table Analysis

The partial life tables for protected *Gonometa* sp. on the two-host plants at Kamaguti for the short and long rain seasons are shown in tables' 4.2- 4.5. The partial life tables for unprotected *Gonometa* sp. for the long rains on the two host plants are shown in tables' 4.10- 4.11. A summary of the real generation mortalities (100rx) for the protected and unprotected larval life stages is given in tables 4.6-4.7 and 4.12 respectively. The highest mortality recorded for the protected larvae was 29.42% for the third instar larvae reared on *Acacia hockii* and was mainly due to disappearance (Table 4.6). The highest mortality of 38% was recorded for the unprotected larvae during the second week after release. It was noted that the mortality percentage (29.75%) during the third week, which was mainly due to disappearance as in the protected larvae, was still high (Table 4.12). The observed total mortality was higher in the unprotected larvae (79.25%) (Table 4.12) in comparison to that of the protected larvae (64% and 77.88%) (Tables 4.6 and 4.7 respectively). *Acacia mearnsii* had a lower mortality percentage (64%) as compared to *Acacia hockii* (77.88%) (Tables 4.6 and 4.7 respectively). The lowest mortality recorded within the two seasons was 2.5% at a second instar stage of larvae reared on *Acacia*

mearnsii. The mortality was quite low during the second season in *Acacia mearnsii* between the first and the third instar stage.

4.3.3 Key- Factor Analysis

The k-values for the various mortality factors are shown in table 4.8. Key factor analysis of the mortality for *Gonometa* sp. is shown in table 4.8. Using Varley and Gradwell (1960) method of key factor analysis, k_3 (Figure 4.2), k_7 and k_{11} (Figure 4.3), which represented mortality due to disappearance (Disappearance of larval stages with no evidence of a factor to be accounted for) of the second, third and fourth instar respectively, showed the most similar trend to change in the total generational mortality (K) (Figure 4.1). k_3 had the most similar trend to the change in generational mortality (K) in comparison to k_{11} and k_7, but it should be noted that disappearance played a key factor role in almost all *Gonometa* sp. larval life stages.

When Podoler and Rogers (1975) method of key-factor analysis was performed, k_1, k_3, k_7, k_{11}, k_{13}, k_{17}, k_{19}, k_{20} had positive relationships with K (Table 4.9). k_{11} (representing mortality due to disappearance at fourth instar) had the highest slope (b=0.322) and the slope was statistically significant (b=0.322; $p > 0.01$).

Table 4.2. Partial ecological life- table for the net-sleeved protected *Gonometa* sp. reared on *Acacia hockii* at Kamaguti, Uasin Gishu District, Kenya during the short rains October 2000-December 2000.

X	Age at start of life instar (Days)	Ix	Dxf	dx	100qx	100rx
I	1	94	Disappearance Total	3 3	3.19 3.19	3.19 3.19
II	9	91	Disappearance *Componotus* ants Total	10 6 16	10.99 6.59 17.58	10.64 6.38 17.02
III	23	75	Disappearance Total	13 13	17.33 17.33	13.83 13.83
IV	35	62	Disappearance Birds Total	2 3 5	3.23 4.77 8.0	2.13 3.19 5.32
V	50	57	Disappearance Birds Total	2 5 7	3.51 8.77 12.28	2.13 5.32 7.45
VI	63	50	Disappearance Birds Total	1 6 7	2.00 12.00 14.00	1.06 6.38 7.44
Pupa	71	43	*Compilura* Unemerged Total	6 2 8	13.95 4.65 14.6	6.38 2.13 8.51
Adult	_____	35	_____	_____	_____	_____

X- age Interval

Ix- Number Surviving at the beginning of Age x

dxf- Factors responsible for mortality (dx)

dx- Number dying during age Interval (x)

100qx- apparent generation mortality (Number dying as a % of the number entering that stage)

100rx- Real generation Mortality (Number dying as a % of the Number at the beginning of the generation)

Table 4.3 Partial ecological life-table for the net sleeve protected *Gonometa* sp. reared on *Acacia mearnsii* at Kamaguti Uasin Gishu District, Kenya during the short rains (October 2000 – December 2000)

X	Age at start of life instar	Ix	Dxf	dx	100qx	100rx
I	1	100	Disappearance	9	9	9
			Total	9	9	9
II	10	91	Disappearance	3	3.3	3
			Unknown	2	2.2	2
			Total	5	5.5	5
III	24	86	Disappearance	9	10.47	9
			Componotus	2	2.33	2
			Unknown	3	3.49	3
			Total	14	16.29	14
IV	36	72	Disappearance	3	4.17	3
			Unknown	1	1.39	1
			Total	4	5.56	4
V	50	68	Birds	4	5.88	4
			Total	4	5.88	4
VI	64	64	Birds	1	1.56	1
			Total	1	1.56	1
PUPA	72	63	Tachinidae *(Compilura* sp.)	12	19.05	12
			Rats	5	7.94	5
			Total	17	26.99	17
ADULT		46	Disappearance	0	0	0
			Ants	0	0	0
			Total	0	0	0

X- age Interval

Ix- Number Surviving at the beginning of Age x

dxf- Factors responsible for mortality (dx)

dx- Number dying during age Interval (x)

100qx- Apparent generation mortality (Number dying as a % of the number entering that stage)

100rx- Real generation Mortality (Number dying as a % of the Number at the beginning of the generation)

Table 4.4 Partial ecological life-table for the net sleeve protected *Gonometa* sp. reared on *Acacia mearnsii* at Kamaguti Uasin Gishu district, Kenya during the long rains (March 2001 - July 2001)

X	Age at start of life instar	Ix	Dxf	dx	100qx	100rx
I	1	100	Disappearance	0	0	0
			Predation	0	0	0
			Total	0	0	0
II	8	100	Disappearance	0	0	0
			Predation	0	0	0
			Total	0	0	0
III	17	100	Disappearance	0	0	0
			Predation	0	0	0
			Total	0	0	0
IV	28	100	Disappearance	2	2	2
			Birds	6	6	6
			Componotus ants	4	4	4
			Total	12	12	12
V	42	88	Disappearance	15	17.05	15
			Birds	25	25.41	25
			Total	40	56.62	40
VI	59	48	Birds	5	10.42	5
			Total	5	10.42	5
PUPA	67	43	*Compilura* sp.	11	25.58	11
			Cocygomimus	3	6.98	3
			Total	14	32.56	14
ADULT		29	_____	_____	_____	_____

X- age Interval

Ix- Number Surviving at the beginning of Age x

dxf- Factors responsible for mortality (dx)

dx- Number dying during age Interval (x)

100qx- apparent generation mortality (Number dying as a % of the number entering that stage)

100rx- Real generation Mortality (Number dying as a % of the Number at the beginning of the generation)

Table 4.5 Partial ecological life- table for the net sleeve protected *Gonometa* sp. reared on *Acacia hockii* at Kamaguti Uasin Gishu District, Kenya during the long rains (March 2001 - July 2001)

X	Age at start of life instar	Ix	dxf	dx	100qx	100rx
I	1	100	Disappearance	7	7	7
			Total	7	7	7
II	17	93	Disappearance	21	22.58	21
			Total	21	22.58	21
III	22	72	Disappearance	32	44.44	32
			Componotus	13	18.06	13
			Total	45	63.5	45
IV	38	27	Disappearance	12	44.44	12
			Birds	4	14.81	4
			Total	16	59.25	16
V	54	11	Disappearance	0	0	0
			Birds	0	0	0
			Total	0	0	0
VI	71	11	Disappearance	1	9.09	1
			Birds	3	27.27	3
			Total	4	36.36	4
PUPA	79	7	*ComponotusI*	3	42.86	3
			Total	3	42.86	3
ADULT		4	_____	_____	_____	_____

X- Age Interval

Ix- Number Surviving at the beginning of Age x

dxf- Factors responsible for mortality (dx)

dx- Number dying during age Interval (x)

100qx- apparent generation mortality (Number dying as a % of the number entering that stage)

100rx- Real generation mortality (Number dying as a % of the number at the beginning of the generation)

Table 4.6 Real generation mortality (100rx) of *Gonometa* sp. reared on *Acacia mearnsii*

Life Stage	Season 1	Season 2	Mean ± SEM
I	9	0	4.5 ± 4.5
II	5	0	2.5 ± 2.5
III	14	0	7 ± 7
IV	4	12	8 ± 4
V	4	40	22 ± 18
VI	4	5	4.5 ± 0.5
PUPA	17	14	15.5 ± 1.5
ADULT	0	0	0
TOTAL	**57**	**71**	**64 ± 7**

Table 4.7 Real generation mortality (100rx) of *Gonometa* sp. reared on *Acacia hockii*

Life Stage	Season 1	Season 2	Mean ± SEM
I	3.19	7	5.1 ± 1.91
II	17.02	21	19.01 ± 1.99
III	13.83	45	29.42 ± 15.59
IV	5.32	16	10.66 ± 5.34
V	7.45	0	3.73 ± 3.73
VI	7.44	4	5.44 ± 1.72
PUPA	8.51	0	4.26 ± 4.26
ADULT	0	0	0
TOTAL	62.76	93	77.88 ± 15.12

Table 4.8 Summary of k-values obtained from partial mortality budget of *Gonometa* sp. reared on *Acacia mearnsii* and *Acacia hockii* for two seasons: October 2000-July 2001

		Acacia mearnsii		*Acacia hockii*	
Life Stage	**Mortality Factor**	1	2	1	2
I-Instar	k_1-Disappearance	0.041	0	0.015	0.032
	k_2-predation	0	0	0	0
II-Instar	k_3-Disappearance	0.015	0	0.015	0.111
	k_4- *Componotus* Ants				
	k_5- Unknown				
	k_6-Predation	0	0	0.03	0
		0.01	0	0	0
		0	0	0	0
III-Instar	k_6-Disappearance				
	k_7-*Componotus* ants	0.048	0	0.038	0.255
	k_9-Predation				
	k_{10}-unknown	0.01	0	0	0
		0	0	0	0
		0.015	0	0	0
IV-Instar	k_{11}-Disappearance	0.018	0.009	0.014	0.255
	k_{12}-Unknown				
	k_{13}-Birds	0.006	0	0	0
	k_{14}-*Componotus*	0	0.027	0.021	0.07
		0.018	0	0	0
V-Instar	k_{15}-Birds	0.027	0.064	0.04	0
	k_{16}-Disappearnce				
		0	0.081	0	0
VI-Instar	k_{17}-Disappearance	0	0	0.009	0.041
	k_{18}-Birds	0.007	0.048	0.056	0.087
PUPA	k_{19}-Tachnidae	0.128	0.091	0.065	0.243
	k_{20}-Rats				
	K_{21}-*Coccygominus*	0.136	0	0	0
	K_{22}-Unemerged	0.031	0	0	0
		0	0	0.02	0
	K-Total	0.51	0.32	0.323	1.094

Table 4.9 Regression analysis of *Gonometa* sp. larval stage specific k-values against the Total K

Instar	k-mortality factor	Regression equation	Sign (p-value)	r^2
I	K_1- Disappearance	Y = 0.006 + 0.028x	0.432	0.322
II	K_3- Disappearance	Y = -0.041 + 0.136x	0.022	0.956
	K_5 – Unknown	Y = 0.003 – 0.001x	0.906	0.009
III	K_7 - Disappearance	Y = -0.089 + 0.039x	0.016	0.967
	K_8 – *Componotus sp.*	Y = 0.003 – 0.001x	0.906	0.009
	K_{10} – Unknown	Y = 0.004 – 0.002x	0.906	0.009
IV	K_{11}- Disappearance	Y = -0.109 + 0.322x	0.024	0.952
	K_{12} – Unknown	Y = 0.002 – 0.001x	0.906	0.009
	K_{13} – Birds	Y = -0.006 + 0.064x	0.202	0.636
	K_{14} - *Componotus sp.*	Y = 0.006 – 0.002x	0.906	0.009
V	K_{15} – Birds	Y = 0.035 – 0.0002x	0.843	0.023
	K_{16} - Disappearance	Y = 0 048 – 0.048x	0.559	0.194
VI	K_{17} – Disappearance	Y = -0.002 + 0.013x	0.304	0.484
	K_{18} – Birds	Y = 0.02 + 0.052x	0.42	0.336
Pupa	K_{19} – Tachnidae (flies)	Y = 0.013 + 0.212x	0.012	0.977
	K_{20} – Rats	Y = - 0.063 + 0.31x	0.223	0.603
	K_{21} – *Coccygomimus*	Y = 0.01 – 0.004x	0.906	0.009
	K_{22} - Unemerged	Y = 0.012 – 0.012x	0.563	0.189

Table 4.10. Partial ecological life-table for the unprotected fourth instar larvae released on *Acacia mearnsii*.

Age at start of life instar	lx	dxf	dx	100qx	100rx
First week	200	Disappearance	62	31	31
		Birds	21	10.5	10.5
		Total	83	41.5	41.5
Second week	117	Disappearance	53	45.29	26.5
		Birds	10	8.55	5.0
		Total	63	53.84	31.5
Third week	54	Disappearance	22	40.74	11
		Birds	8	14.81	4
		Total	30	55.55	15
Fourth week	24	Disappearance	14	58.33	7
		Total	14	58.33	7
Spun	10	Tachnidae	3	30	1.5
		Total	3	30	1.5
Adult	7				

Table 4.11. Partial ecological life table for the disappearance rate for the unprotected fourth instar larvae released on *Acacia Hockii*

Age at start of life instar	Ix	dxf	dx	100qx	100rx
First week	200	Disappearance	5	2.5	2.5
		Total	5	2.5	2.5
Second week	195	Disappearance	52	26.67	26
		Birds	37	18.97	18.5
		Total	89	45.64	44.5
Third week	106	Disappearance	82	77.36	41.0
		Birds	7	6.6	3.5
		Total	89	83.96	44.5
Fourth week	17	Disappearance	15	88.24	7.5
		Total	15	88.24	7.5
Spun	2				
Adult	2				

Table 4.12 Real generation mortality for unprotected released on host plants

Life stage	*Acacia mearnsii*	*Acacia hockii*	Mean + SEM
First week	4.5	2.5	3.5 ± 1
Second week	31.5	44.5	38 ± 6.5
Third week	15	44.5	29.75 ± 14.75
Fourth week	7	7.5	7.25 ± 0.25
Spun	1.5	0	0.75 ± 0.75
Total	59.5	99	79.25 ± 19.75

4.13. Summary of k-values obtained from partial mortality budget of *Gonometa* sp. released on *Acacia Mearnsii* and *Acacia Hockii* during the second season: March 2001-July 2001.

Life instar	Mortality factor	*A.Mearnsii*	*A.hockii*
1st week	k_1-Disappearance	0.16	0.01
	k_2-birds	0.05	0
2nd week	k_3-Disappearance	0.26	0.13
	k_4-Birds	0.04	0.09
3rd week	k_5-Disappearance	0.22	0.65
	k_6-Birds	0.07	0.03
4th week	k_7-Disappearnce	0.38	0.93
Spun	k_8-Tachnidae	0.15	0

Figure 4.1. K-total values against seasons

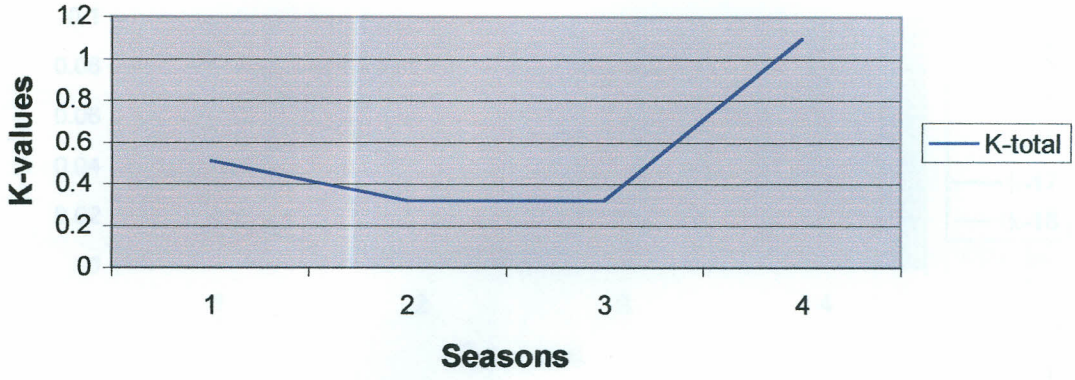


Figure 4.2. k_1-$k_7$values against seasons

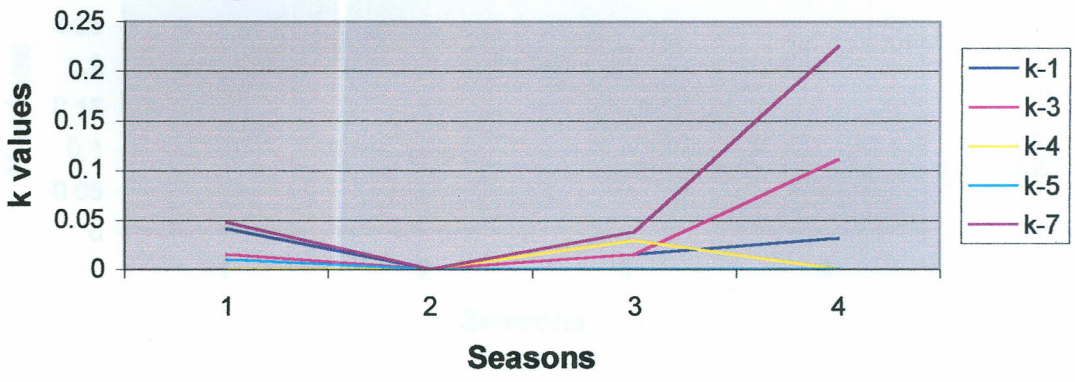


Figure 4.3. k_8-k_{13} values against seasons

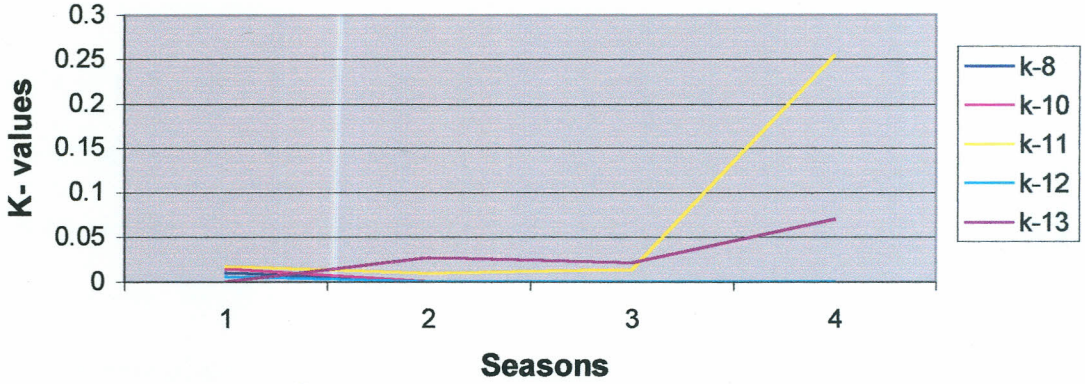


Figure 4.4. k_{14}-k_{18} values against Seasons

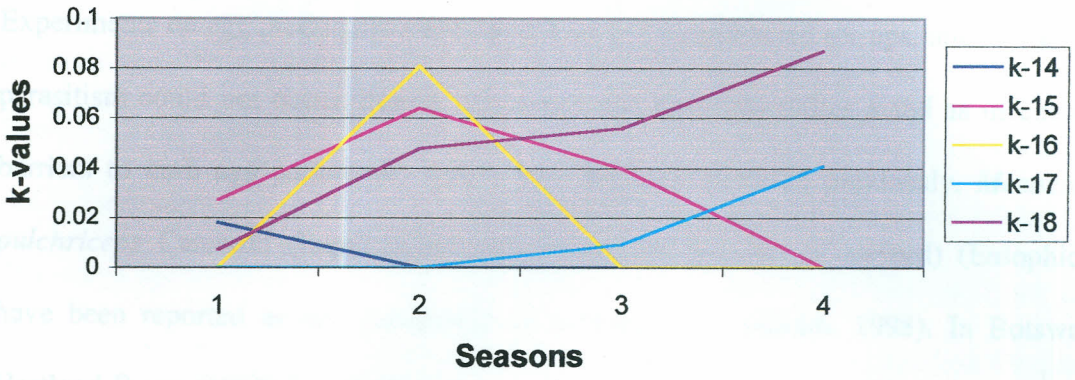
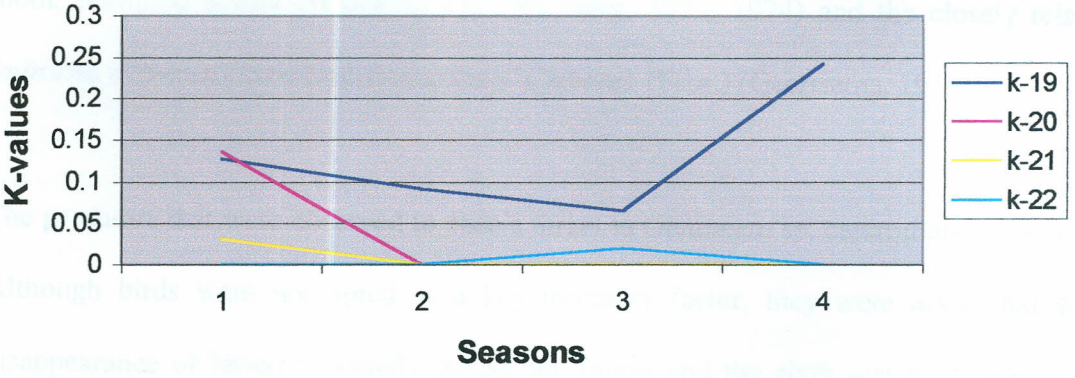


Figure 4.5. k_{19}-k_{22} values against Seasons



4.4 DISCUSSION

Experiments on egg production were carried out in two protected set-ups, and as such egg parasitism could not occur. Plastic containers and net sleeves thus acted as mechanical barriers to curb egg parasitism, which have been encountered previously. *Mesocomys pulchriceps* Cameron (Eupelmidae) and *Peddiobius anastati* (Crawford) (Eulophidae) have been reported as egg parasitoids of *Gonometa* sp. (Kioko, 1998). In Botswana, Hartland-Rowe (1992) found *Mesocomys pulchriceps* attacking eggs of *G.rufobrunea* in the field and in South Africa, it has been recorded attacking eggs of the edible mopane moth, *Imbrasia belina* (Westw.) (Van Den Berg, 1971, 1974) and the closely related *Imbrasia cytherea clarki* Geertsema and *I. Cytherea* (Fabr.) (Geertsema, 1975).

The predators that were observed to pose a threat to *Gonometa* sp. caterpillars were birds. Although birds were not noted as a key mortality factor, they were associated with disappearance of larvae especially during the fourth and the sixth instar. *Componotus* ants (Formicidae) that were observed predating on *Gonometa* sp. larvae have also been reported as predators by other researchers in different parts of Africa especially in relation to tsetse fly predation (Fiske, 1920; Carpenter, 1920; Rogers and Randolph, 1984). A pentatomid bug, *M. sprurcata*, which was found crawling on net sleeves with *Gonometa* larvae has been reported to suck body fluids and kill *Argema mimosae* larvae (Kioko, 1998). The species belongs to the same sub-family Asopinae with *Podisus maculiventris*, which in North America feeds mainly upon hairless lepidopteran larvae and one individual is recorded to have consumed 123, third and fourth instar larvae of the armyworm *Laphgma exigua* Hbn. during a period of nine weeks (Wilson, 1933). Though

pentatomids are mainly phytophagus, the sub-family has developed predatory habits and their salivary glands produce an alkaline secretion that is injected into the body of the host acts as a poisoning or paralyzing agent (Elson, 1937).

The parasitoids observed from *Gonometa* sp. cocoons in this study were from Tachinidae and Ichneumonidae families. The same families had been recorded by Kioko (1998) from *Gonometa* sp. in Mwingi District, Kenya and they are similar to those recorded from *Gonometa rufobrunnea* in Botswana (Hartland-Rowe, 1992). Unidentified Parasitoid cocoons observed attached to *Gonometa* larva (Plate 4.1) could be evidence to suggest that the parasitoids lay eggs on or in the larvae. Hartland-Rowe (1992) proposed that parasitoids lay eggs in or on larvae and later the adult parasitoids emerge from the cocoons. Marsh (1937) observed that a few Ichneumonid wasps specialize on pre-pupal larvae, being attracted by the smell of the freshly spun silk. They insert their ovipositors through the partially spun cocoons and lay eggs in the pre-pupal larvae. Such Ichneumonid parasitoids have only a narrow window of opportunity in which to locate and oviposit on the spinning larvae as once the cocoon has hardened, the ovipositor of the parasitoid cannot penetrate it. Further observations need to be carried out to confirm the stage at which the parasitoid attacks its host. This will help in developing protective mechanism for the larvae hence quality cocoons.

The mortality rate observed during the developmental period of *Gonometa* sp. larvae in this study was higher (99%) in the unprotected larvae than in the protected larvae (77.88%) in *Acacia hockii*. The highest mortality (99%) was recorded in larvae reared on unprotected *Acacia Hockii* while the lowest mortality (57%) was recorded in larvae

reared on protected *Acacia mearnsii*. This is a good indication that the net sleeves acted as mechanical barriers for the natural enemies. The impact of nets sleeves as a protective device was reduced by birds, which tore net sleeves with their beaks to get their prey, but it could be used effectively as a mechanical barrier.

Disappearance was the key mortality factor and it involved factors that could not be singled out easily especially predators (Birds) and escape of the larvae through the net pores. Tachnidae flies (*Compirura* sp.), C*occymimus,* rats and unmerged cocoons were the factors that reduced the quantity and quality of the *Gonomet*a sp. cocoons during the pupal developmental stage.

Tachnidae flies (*Compirura* sp.) and C*occymimus* emerged from the cocoons after the larvae spun. This pupal parasitoid leaves unanswered question whether they lay eggs on larvae or pitch to lay eggs to freshly spun cocoon. The rats made holes through the outer shell of the cocoons to eat the pupa.

CHAPTER FIVE

5.0. GENERAL DISCUSION, CONCLUSION AND RECOMENDATIONS

5.1. GENERAL DISCUSION

In the past, economic incentives in Uasin Gishu district, Kenya, have forced dependence on primary production, largely in agriculture, for sustaining demands for food and wealth to improve the people's living standards. Extensive agriculture and population growths are among the main causes of the rapid dwindling of the region's rich biodiversity (Kioko, 1998). Wild silk production could diversify the rural people's economic base, and therefore, encourage them to be allied with the current world efforts in promulgating conservation-based development The fact that *Gonometa* sp. is distributed widely in Uasin Gishu district indicates a very good potential area for wild silk farming.

Although *Gonometa* sp. host plants are widely distributed in the district, deforestation is high due to population pressure. The trees are also preferred for other purposes like charcoal burning and construction poles. To improve on the conservation of these wild silk moth host plants, it calls for economic incentives that integrate biological conservation with the economic development for the people. The introduction of wild silk production may offer an economic incentive to farmers in the district. If the farmers can harness income from the wild *Gonometa* sp. silk moths feeding on these trees, then there will be a voluntary change of attitude and conservation of these host plants can be enhanced. Such kind of voluntary changes in behavior towards insect conservation for income generation has been reported in Malawi (Munthali and Mughogho, 1992).

The time of emergence of an individual adult insect is determined by the underlying physiological rhythms that are governed by the environmental factors. The *Gonometa* sp. had two generations a year with adult moths emerging during the onset of long and short rain seasons thus farmers could have two harvests per year under natural conditions. This is probably an adaptation to the sharp seasonality of rainfall in East Africa, which consists of two wet and dry seasons. Sinha and Chaudhuri (1992) reported that a close relationship exists between rain and the emergence phenology of tasar silk moth, *A. mylitta.* The natural environment signals dictate its developmental fate and regulate the whole mechanism by which a somewhat synchrony is achieved. Further, the appearance of suitable food for the establishment of young larvae on host plants that also reflushes with abundant leaves during the rainy season also provides optimum life conditions for the silk moths. The study also shows that the larval developmental period at Kamaguti, Uasin Gishu, district takes longer period (Table 3.3) in comparison to studies done by Kioko (1998) at Nguni, Mwingi district. The differences were attributed to climatic differences of the two localities.

The ability of *Gonometa* sp. moths to lay eggs in an enclosed ventilated plastic containers and net sleeves confers well with Kioko's (1998) report that the species may not be host specific with regard to oviposition. This suggestion concurs with the findings of Hartland –Rowe (1992) who reported that, *G. rufobrunnea* in northern Botswana does not usually lay eggs on the food plant, mophane but on thin stems of grasses or other herbage beneath bushes, though sometimes a batch is laid upon a mophane leaf. This characteristic behaviour in the African wild silk moths can be used to enhance the laboratory egg production for the supply to different farmers and prevent egg parasitism.

In this study, there were a number of parasitiods and predators recorded attacking silk moths at different developmental stages. Since egg production was done in the protected environments (Net sleeves and plastic containers) no egg parasitism was evidenced. However, Kioko (1998) reported Hymmenoptera parasitiods, *Mesocomys pulchriceps* and *pediobius anastati* as egg parsitiods for *Gonometa* sp. at Nguni, Mwingi district. This indicates that eggs can be parasitoid free if they are produced in a laboratory. Weseloh (1993) reported that parasitoids tend to have a narrower habitat tolerance than their hosts and that hosts may be able to escape parasitization by colonizing a new plant species or microhabitat. Tuskes *et al* (1996) indicated that the host-parasitoid relationship is an evolutionary game of hide and seek. The environmental manipulation can be used to desynchronize the silk moth and parasitoid life cycles.

The net-sleeves and plastic containers used for egg production in this study are some of the possible ways that could be developed further to come out with a possible grainage for wild silk moths. The study also showed that infertility was high in plastic containers environment than in the net sleeves environment (Table 3.6). The infertility was associated with the surface area and preference of the plastic container materials. The net sleeves have more open space for mating in comparison to the plastic containers used. The infertility could also be reduced by increasing the number of males in any of the mating and oviposition environments.

Survival rate for the protected larvae was higher than that of the unprotected. The highest mortality recorded for the protected larvae was 29.42% (Table 4.7) and was mainly due to disappearance. The highest mortality recorded for the unprotected larvae was 38%

during the second week after releasing the larvae (Table 4.12). The lowest mortality recorded within the two seasons was 2.5%. This was a good indication that the net sleeves acted as a mechanical barrier to some of the natural enemies. Kioko (1998) reported significant reduction in larval mortality on *Gonometa* sp. reared in net sleeves on *Acacia elation* at Nguni, Mwingi district.

Gonometa sp. caterpillar posse's spines and cryptic colouration probably as defensive mechanism and also to escape from predators. They have a tendency to remain sedentary below the host branches and at or near the bottom of the stem during the day. In another group of Lepidoptera, the sphingids, Schmidt (1990) also observed larvae cryptic colouration combined with a general tendency to remain relatively sedentary as means of escape from predation. The pupal stage of the silk moths is enclosed in a dull brown silk cocoon with sharp spines around the outer shell (Plate 3.4). This developmental stage was observed to occur during a dry spell or cold period when the temperatures are high and low respectively. The pupal cocoon cases could have been developed to avoid climatic extremes or predation or both.

Pupal diapause in the African wild silk moths of the family Lasiocampidae was reported by Pinhey (1975) who noted that a few of these moths spend years in the cocoon state awaiting favourable season to emerge. In Japan, Masaki (1980) observed that Lasiocampidae moths enter summer diapause as pupae and winter diapause as eggs. It has been reported that pupal diapause in the wild silk moths of the genus *Antheraea* can be manipulated through a change in the environmental conditions (Janarthanan *et al.*,

1994; Chowdharry *et al.,* 1996). Manipulation of the pupal diapause can be used to enhance seed production.

Distinct sexual dimorphism was evident in the *Gonometa* sp. cocoons and the adult moths. The male cocoons and moths are both smaller than females (Plates 3.4 and 3.5 respectively). This sexual dimorphism in the adults has also been reported in the wild silk moth, *Anaphe venata* in Nigeria (Ashiru, 1991). Sexual dimorphism of adults could be advantageous for commercial silk production. Since *Gonometa* sp. cocoons are used as seeds for breeding, wild silk farmers can sort them out easily. The following conclusions were made from this study.

1. The moth's oviposition was bimodal for a year. Moths laid eggs to two protected Unnatural environments (Net sleeves and Plastic containers). The incubation period of eggs in the two environments was significantly different at $p<0.05$ with plastic containers environment having the shortest period.

2. The *Gonometa* sp. larvae were observed feeding on two host plants (*Acacia hockii* and *Acacia mearnsii)* that were abundant in the area. The mean larval period was 72.75 $\pm$ 1.83 days for the larvae reared on *A. mearnsii* and 99.15 + 4.95 for *A. hockii.* The larval period was significantly different ($P<0.05$) between the host plants.

3. The *Gonometa* sp., cocoon size and weight varied within the sexes. The female cocoons were larger than the male cocoons with the cocoons mean length and

mean width being significantly different at $P<0.05$ within the sexes. The size of the cocoons can be used precisely for easier identification of sex.

4. The pupa has diapause period in December-February and June- September. Male larvae spin earlier than the female larvae, but moths of the two sexes emerge almost at the same time and mate. This explains well why males seem to take a longer diapause period than the females in each of the two seasons.

5. The Adult wing length was significantly different at $p<0.05$ ($p=0.039$). The sexual dimorphism exhibited in both pupal and adult stage can be used precisely for identification and separation of sexes during breeding period.

6. Fecundity for the moths kept in the Net sleeve environment was higher than in plastic containers. Eggs in plastic containers had the highest infertility percentage (51.65%).

7. The mortality rate observed during the developmental period of *Gonometa* sp. larvae in this study was higher in the unprotected than in the protected larvae.

5.2. RECOMMENDATIONS AND SUGGESTION FOR FUTURE STUDIES

This study was carried out in a high potential area for agricultural activities. The area is also abundant with *Acacia mearnsii* trees that would be recommended for wild silk farming. This Acacia species is thornless and grows very fast and it can be trimmed to

produce numerous branches. The *Acacia mearnsii* flowers are also ideal for honey production since bees collect pollen and nectar from them. This implies that the wild silk sericulture and apiculture activities could be combined, which is an added advantage to the farmers. This *Acacia* species maintains green forage throughout the year, which is an added advantage to wild silk farmers.

Since this research was carried out on two host plants, *Acacia Mearnsii* and *Acacia hockii* cross-host rearing research would be recommended to ensure enough food for larvae throughout the year. The *Acacia mearnsii* maintains forage throughout the year while *Acacia hockii* sheds leaves during the dry spell. Based on the findings of this study that there was difference on larval developmental period reared on the two host plants, further research would be recommended on the physiological differences of the hot plant

Further research could be focused on grainage methods. To ensure mass rearing of larvae, eggs should be produced in well-protected area, as the results in this study recorded no egg parasitism in the two set-ups used (Plastic containers and net sleeves). The plastic containers would be recommended for indoor *Gonometa* sp. egg mass production but they need more improvisation since infertility was high in them. Oviposition preference materials need also to be verified to ensure maximum fertility of moths. The pupal diapause encountered in this study also needs to be manipulated to break and ensure a continuous production per annum.

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1. Appendix, Incubation period of *Gonometa* sp. eggs during the first season (October 2000-December 2000)

Season	Environment.	Month	Incubation period	Temperature	Humidity
1	Soap dish	October	13	25	70
1	Soap dish	October	13	25	71
1	Soap dish	October	14	25	71
1	Soap dish	October	14	25	71
1	Soap dish	October	14	25	71
1	Soap dish	October	15	25	71
1	Soap dish	October	14	25	71
1	Soap dish	October	15	25.5	70
1	Soap dish	October	14	25.5	70
1	Soap dish	October	14	25.5	70
1	Soap dish	November	13	25.5	62
1	Soap dish	November	13	25.5	62
1	Soap dish	November	13	25.5	62
1	Soap dish	November	13	23.5	66
1	Soap dish	November	14	24.5	61.5
1	Soap dish	November	15	23.5	63.5
1	Soap dish	November	14	23.5	63.5
1	Soap dish	November	14	23.5	63.5
1	Soap dish	November	13	24.5	61.5
1	Soap dish	November	14	23.5	63.5
1	Soap dish	November	15	23	55.5
1	Soap dish	November	15	23	55.5
1	Soap dish	November	13	21	70.5
1	Soap dish	November	14	21	70.5
1	Soap dish	November	13	23	80.5
1	Soap dish	November	14	22.5	69.5
1	Soap dish	November	12	22.5	72
1	Soap dish	November	13	22.5	69.5
1	Soap dish	November	13	22.5	72
1	Soap dish	November	14	22	72
1	Soap dish	November	15	22	72
1	Soap dish	November	13	22.5	72
1	Soap dish	November	12	22.5	72
1	Soap dish	November	13	20	62
1	Soap dish	November	13	20.5	62.5
1	Soap dish	December	14	24.5	62.5
1	Net sleeve	October	17	25.5	70
1	Net sleeve	October	17	25.5	70
1	Net sleeve	October	18	25	70.5
1	Net sleeve	October	19	24.5	66.5
1	Net sleeve	October	19	24.5	66.5
1	Net sleeve	October	20	24.5	61.5

1	Net sleeve	October	18	24.5	61.5
1	Net sleeve	October	19	24.5	61.5
1	Net sleeve	October	18	25	62
1	Net sleeve	October	20	25	62
1	Net sleeve	November	17	24.5	59
1	Net sleeve	November	18	24.5	61
1	Net sleeve	November	19	24	61.5
1	Net sleeve	November	20	22.5	60.5
1	Net sleeve	November	18	23	64
1	Net sleeve	November	16	23	64
1	Net sleeve	November	17	24.5	63.5
1	Net sleeve	November	17	24.5	63.5
1	Net sleeve	November	17	24.5	63.5
1	Net sleeve	November	19	24.5	63.5
1	Net sleeve	November	19	22.5	64
1	Net sleeve	November	19	22.5	64
1	Net sleeve	November	17	23	69.5
1	Net sleeve	November	18	23	69.5
1	Net sleeve	November	18	22	69.5
1	Net sleeve	November	17	22	72
1	Net sleeve	November	16	19.5	73.5
1	Net sleeve	November	18	20.5	69.5
1	Net sleeve	November	18	20.5	69.5
1	Net sleeve	November	17	20.5	69.5
1	Net sleeve	November	17	20.5	69.5
1	Net sleeve	November	17	22	62.5
1	Net sleeve	November	17	22	62.5
1	Net sleeve	November	16	23	65
1	Net sleeve	December	17	22.5	57
1	Net sleeve	December	17	23	64
1	Net sleeve	December	17	24.5	62
1	Net sleeve	December	17	24.5	62
1	Net sleeve	December	18	24	57

2. Appendix, Incubation period of *Gonometa* sp. eggs during the second season (March 2001-June 2001)

Season	Environment.	Month	Incubation period	Temperature	Humidity
2	Soap dish	March	14	19.5	83
2	Soap dish	March	14	19.5	83
2	Soap dish	April	15	22	65.5
2	Soap dish	April	15	22	65.5
2	Soap dish	April	13	22	65.5
2	Soap dish	April	13	22	65.5
2	Soap dish	April	15	22	65.5
2	Soap dish	April	15	22	65.5
2	Soap dish	April	15	21.5	55
2	Soap dish	April	14	21.5	55
2	Soap dish	April	14	21.5	55
2	Soap dish	April	14	21.5	55
2	Soap dish	April	14	21.5	55
2	Soap dish	April	15	23.5	58
2	Soap dish	April	16	23.5	58
2	Soap dish	April	15	23.5	58
2	Soap dish	April	15	23.5	58
2	Soap dish	April	15	23.5	58
2	Soap dish	April	15	23.5	58
2	Soap dish	April	15	24	65
2	Soap dish	April	15	23	69.5
2	Soap dish	April	14	23	69.5
2	Soap dish	April	15	23	69.5
2	Soap dish	May	14	22	74.5
2	Soap dish	May	14	22	74.5
2	Soap dish	May	14	22	74.5
2	Soap dish	May	14	23	69.5
2	Soap dish	May	14	23	69.5
2	Soap dish	May	15	21.5	78.5
2	Soap dish	May	16	22.6	79
2	Soap dish	May	17	21.5	78.5
2	Soap dish	May	18	21.5	72
2	Soap dish	May	18	21.5	72
2	Soap dish	May	17	20.5	67
2	Soap dish	May	17	20.5	67
2	Soap dish	June	16	15.5	79
2	Soap dish	June	17	15.5	79
2	Net sleeve	March	14	21.5	65
2	Net sleeve	March	16	21.5	65
2	Net sleeve	March	16	21.5	68.5
2	Net sleeve	March	16	21	68.5
2	Net sleeve	April	18	22	65.5

2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	19	22	65.5
2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	17	22	65.5
2	Net sleeve	April	14	21.5	55
2	Net sleeve	April	17	21.5	55
2	Net sleeve	April	18	21.5	55
2	Net sleeve	April	17	21.5	55
2	Net sleeve	April	19	23.5	58
2	Net sleeve	April	17	23.5	58
2	Net sleeve	April	17	24	65
2	Net sleeve	April	18	24	65
2	Net sleeve	April	17	24	65
2	Net sleeve	April	18	23	69.5
2	Net sleeve	April	18	23	69.5
2	Net sleeve	April	18	19.5	79
2	Net sleeve	April	18	19.5	79
2	Net sleeve	April	19	19.5	79
2	Net sleeve	April	18	19.5	79
2	Net sleeve	April	18	18	85
2	Net sleeve	April	22	22	61
2	Net sleeve	April	20	22	61
2	Net sleeve	April	23	22	61
2	Net sleeve	April	22	22	61
2	Net sleeve	April	22	22	61
2	Net sleeve	April	21	22	63.5
2	Net sleeve	April	22	22	63.5
2	Net sleeve	April	22	22	63.5
2	Net sleeve	April	20	22	63.5
2	Net sleeve	April	20	22	63.5
2	Net sleeve	April	19	22	63.5
2	Net sleeve	April	19	22	63.5
2	Net sleeve	April	19	23	62
2	Net sleeve	April	19	23	62
2	Net sleeve	April	19	23	62
2	Net sleeve	April	19	23	61

3. Appendix, k- values for partial mortality budget for *Gonometa* sp. reared on *Acacia hockii* (March 2001-July 2001)

Life Stage	Number observed unless Marked *	Log 10	k-value
I-Instar	100	2	
k_1-Disappearance	7		0.032
	93*	1.968	
II- Instar	93	1.968	
k_3-Disappearance	21		0.111
	72*	1.857	
III- Instar	72	1.857	
k_7- Disappearance	32		0.255
	40*	1.602	
k_8-*Componotus*	13		
	59*	1.771	
IV-Instar	27	1.431	
k_{11}-Disappearance	12		0.255
	15*	1.176	
k_{13}-Birds	14		
	23*	1.361	0.07
V-Intar	11	0	0
k_{16}- Disappearance	0	0	0
k_{15}-Birds	0	0	0
VI-Instar	11	1.041	
k_{17}- Disappearance	1		0.041
	10*	1	
k_{18}-Birds	3		0.087
	9*	0.954	
Pupa	7	0.854	
k_{19}- *Compilura*	3		0.243
	4*	0.602	
Adults	4	_____	_____

4. Appendix, k- values for partial mortality budget for *Gonometa* sp. reared on *Acacia hockii* (October 2000-December 2000)

Life Stage	Number observed unless marked *	Log 10	k-value
I-Instar	94	1.974	
k_1-Disappearance	3		0.015
	91*	1.959	
II- Instar	91	1.959	
k_3-Disapperance	10		0.051
	81*	1.908	
k_4-*Componotus*	6		0.03
	85*	1.929	
III- Instar	75	1.875	
k_7- Disappearance	13		0.0383
	62*	1.792	
IV-Instar	62	1.792	
k_{11}-Disappearance	2		0.014
	60*	1.778	
k_{13}-Birds	3		0.021
	59*	1.771	
V-Instar	57	1.756	
k_{16}- Disappearance	2		0.016
	55*	1.74	
k_{15}-Birds	5		0.04
	52*	1.716	
VI-Instar	50	1.699	
k_{17}- Disappearance	1		0.009
	49*	1.69	
k_{18}-Birds	6		0.056
	44*	1.643	
Pupa	43	1.643	
k_{19}- *Compilura*	6		0.065
	37*	1.568	
	2		0.02
	41*	1.613	
Adults	35		

5. Appendix, k- values for partial mortality budget for *Gonometa* sp. reared on *Acacia mearnsii* (March 2001-July 2001)

Life Stage	Number observed unless marked *	Log 10	k-value
I-Instar	100	0	0
k_1-Disappearance	0	0	0
k_2-Predation	0	0	0
II- Instar	100	0	0
k_3-Disapperance	0	0	0
k_6-Predation	0	0	0
III- Instar	100	0	0
k_7- Disappearance	0	0	0
k_9-Predation	0	0	0
IV-Instar	100	2	
k_{11}-Disappearance	2		0.009
	98*	1.991	
k_{13}-Birds	6		0.027
	94*	1.973	
k_{14}-*Componotus*	4		0.018
	96*	1.982	
V-Instar	88	1.944	
k_{16}- Disappearance	15		0.081
	73*	1.863	
k_{15}-Birds	25		0.064
	63*	1.799	
VI-Instar	48	1.681	
k_{18}-Birds	5		0.048
	43*	1.633	
Pupa	43	1.633	
k_{19}- *Compilura*	11		0.128
	32*	1.505	
k_{21}-*Coccygomimus*	3		0.031
	40	1.602	
Adults	29	____	____

6. Appendix, k- values for partial mortality budget for *Gonometa* sp. reared on *Acacia mearnsii* (March 2001-July 2001)

Life Stage	Number observed unless marked *	Log 10	k-value
I-Instar	100	2	
k_1-Disappearance	9		0.041
	91*	1.959	
II- Instar	91	1.959	
k_3-Disappearance	3		0.015
k_5-Unknown	88*	1.944	
	2		0.01
	89*	1.949	
III- Instar	86	1.934	
k_7- Disappearance	9		0.048
k_8-*Componotus*	77*	1.886	
k_{10}-Unknown	2		0.01
	84*	1.924	
	3		0.015
	83*	1.919	
IV-Instar	72	1.857	
k_{11}-Disappearance	3		0.018
k_{12}-Unknown	69*	1.839	
	1		0.006
	71*	1.851	
V-Instar	68	1.833	
k_{15}-Birds	4		0.027
	64*	1.806	
VI-Instar	64	1.806	
k_{18}-Birds	1		0.007
	63*	1.799	
Pupa	63	1.799	
k_{19}- *Compilura*	12		0.019
k_{20}-Rats	51*	1.708	
	5		0.136
	46*	1.663	
Adults	46	0	0

7. Appendix, k values for partial mortality budget for unprotected *Gonometa* sp. released on *Acacia mearnsii*.

Life stage	Number observed unless marked*	Log 10	k-value
1st week	200	2.3	
	62		0.16
k_1-Dissappearance	138*	2.14	
	21		0.05
	179*	2.25	
k_2-Birds			
2nd week	117	2.07	
	53		0.26
k_3-Dissappearnce	64*	1.87	
	10		0.04
k_4-Birds	107*	2.03	
3rd week	54	1.73	
k_5-Disappearance	22		0.22
	32*	1.51	
k_6-Birds	8		0.07
	46*	1.66	
4th week	24	1.38	
k_7-Disappearance	14		0.38
	10*	1.0	
Spun	10	1	
k_8-Tachnidae	3		0.15
	7*	0.85	

8. Appendix, k values for partial mortality budget for unprotected *Gonometa* sp. released on *Acacia mearnsii*.

Life stage	Number observed unless marked*	Log 10	k-value
1st week	200	2.3	
	5		0.01
k_1-Disappearance	195*	2.29	
2nd week	195	2.29	
	52		0.13
k_3-Disappearnce	143*	2.16	
	37		0.09
k_4-Birds	158*	2.2	
3rd week	106	2.03	
k_5-Disappearance	82		0.65
	24*	1.38	
k_6-Birds	7		0.03
	99*	2.00	
4th week	17	1.23	
k_7-Disappearance	15		0.93
	2*	0.3	