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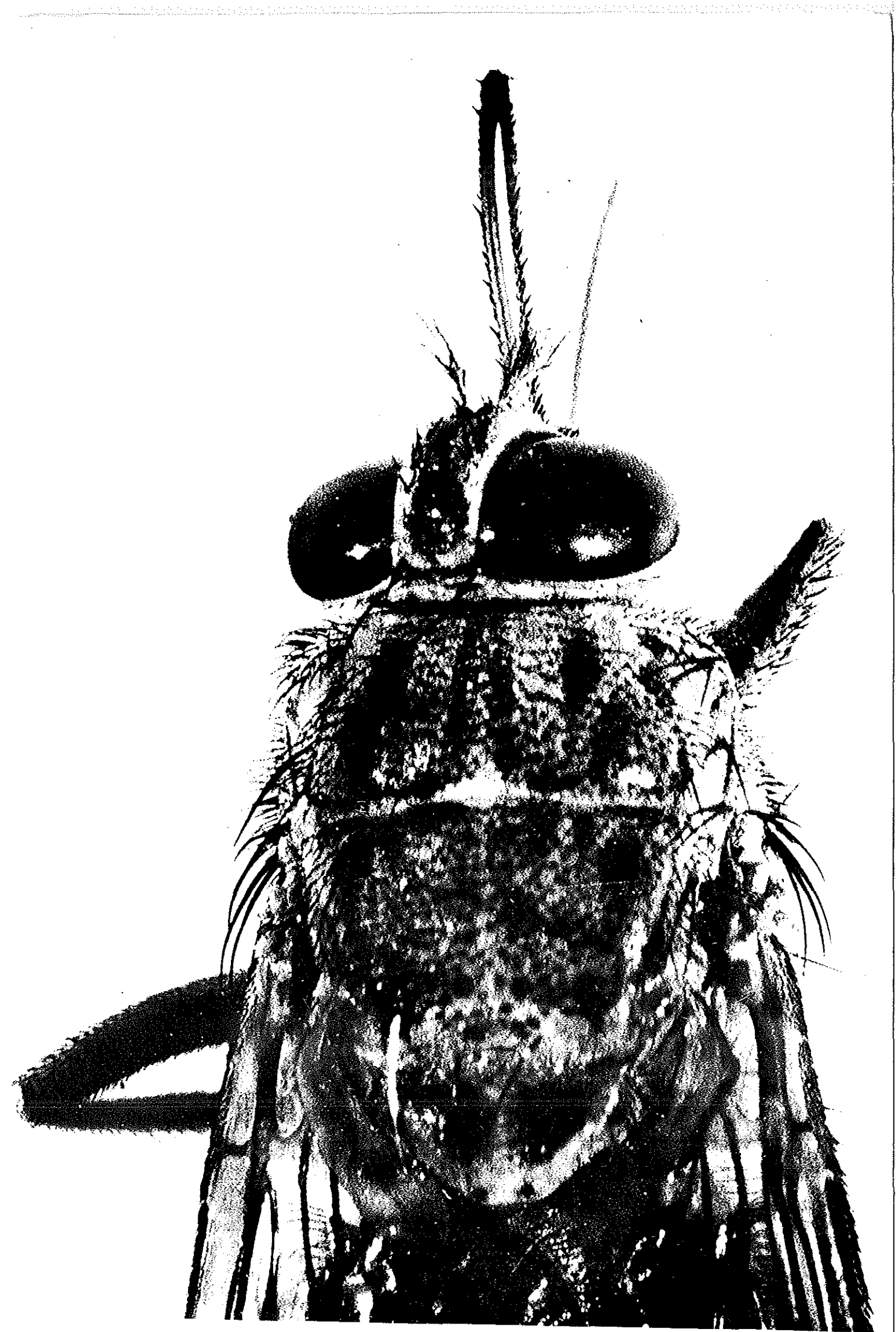
SCHOOL OF GRADUATE STUDIES

Studies on the tsetse flies
of the Finchaa River
Valley

by
Getachew Tikubet

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STUDIES ON
THE
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OF THE FINCHA RIVER VALLEY

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Getachew Tikubet

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School of Graduate Studies

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Faculty of Science

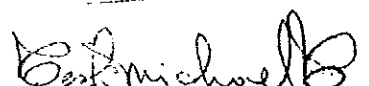
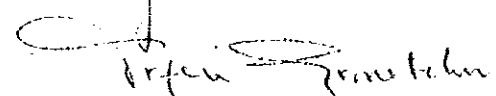
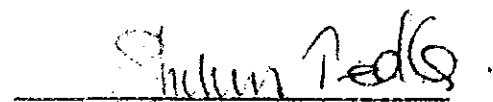
Approved by:

Dr. D.M. Wintor
External Examiner

Dr. Tesfemichael T. Yohanes
Internal Examiner

Dr. Teferi Gemetchu
Research Advisor

Dr. Shibru Tedla
Chairman



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Abstract

A year-round ecological study of G. morsitans ugandensis was carried out from September 1980 to August, 1981 in the Finchaa River Valley in the Western part of Ethiopia.

Three different sampling methods, namely Vehicle Patrol method, Screen/Hand net method and Biconical Traps were employed. All were found to be effective.

The mono-species composition, the unimodal seasonal fluctuation and the biphasic diel activity of the tsetse flies of the area were determined.

The effect of various factors (eg. climate, altitude, vegetation, etc.) that interplay with the eco-distribution of this species of tsetse fly were statistically tested. Conditions related to temperatures, rainfall vegetation and bush-fire affected the fly population and distribution.

The apparent density (A.D.) was high during and after the rainy seasons and low during the dry season. The sex ratio indicated that more males were captured with the Vehicle Patrol and Screen/Hand net methods while the reverse was the case with the Biconical Traps.

The age structure of the flies showed that most of the flies were in the pre-reproductive and reproductive stages.

Observations on the physiological condition of the flies depicted a very high proportion of hungry flies and a relatively low fed and pregnant flies.

Blood-meal analysis carried out on G.m. ugandensis in Finchaa showed man, wild pig and warthog to be the main vertebrate hosts.

The infection rate of flies in the valley was low, although a fairly high infection rate in cattle was observed on the edge of the escarpment.

1. INTRODUCTION

Trypanosomiasis is a very serious and deadly disease of man, cattle and other domestic animals. African trypanosomiasis is confined to countries south of the Sahara. The area affected is an enormous block of the African land mass extending from approximately 14°N to southern Angola at 29°S, with continuous and isolated areas of infestation (Ford, 1970). The ramifications of the trypanosomiasis problem are immense and the diversity in different circumstances is innumerable. Trypanosomiasis of man and animals constitute not only a health hazard but also imposes a major constrain on livestock production and general agricultural development. An estimated 10 million square kilometers, or nearly a quarter of the area of the African continent, is largely denied to cattle and indeed to many other domestic animals. Apart from this, the production of commodities (eg. sugar, cotton, etc.) and energy (eg. electricity) for local usage and/or export is hampered.

The importance of trypanosomiasis has long been known to the African stockman. However, it was not until turn of the century that the presence of small, highly motile, flagellated protozoan in the blood of infected cattle was observed by research workers. Observations carried out between 1895 and 1905, and thereafter established the identity and significance of these organisms as the true cause of cattle trypanosomiasis (Nagana) and human trypanosomiasis (sleeping sickness) within the fly belts. Studies on the morphology of the parasites and the type of the diseases they cause revealed that there were at least two distinct species of trypanosomes (*T. rhodesiense* and *T. gambiense*) parasitizing man and three other species of trypanosomes (*T. brucei*, *T. vivax*, *T. congolense*) parasitizing cattle. These parasites also showed marked difference in their virulence to their hosts. Other *Trypanosoma* species also parasitize such animals like crocodiles, bats, rodents, etc. (Mulligan, 1970). *T. simae* and *T. suis* affect pigs and many other trypanosomes infect other animals.

In cattle the two most important are *T. congolense* and *T. vivax*. Both may cause either mild and chronic infections or acute and fatal disease (Mulligan, 1970). *T. congolense* is sometimes regarded as the cause of the greatest economic losses due to loss of weight and death of cattle, while *T. vivax* more usually causes mild disease. However, the roles of these

parasites may be reversed in different areas. The disease caused by T. brucei, in cattle, is often of little pathological significance.

In man, sleeping sickness is caused by T. gambiense (Gambian sleeping sickness) and T. rhodesiense (Rhodesian sleeping sickness). The Gambian sleeping sickness is found in different areas of west, central and east Africa. T. gambiense infection in man is chronic and is transmitted by the palpalis Group of tsetse flies. T. rhodesiense infection, on the other hand, develops more quickly in man and is mainly transmitted by the morsitans Group (Mulligan, 1970; Ford, 1971).

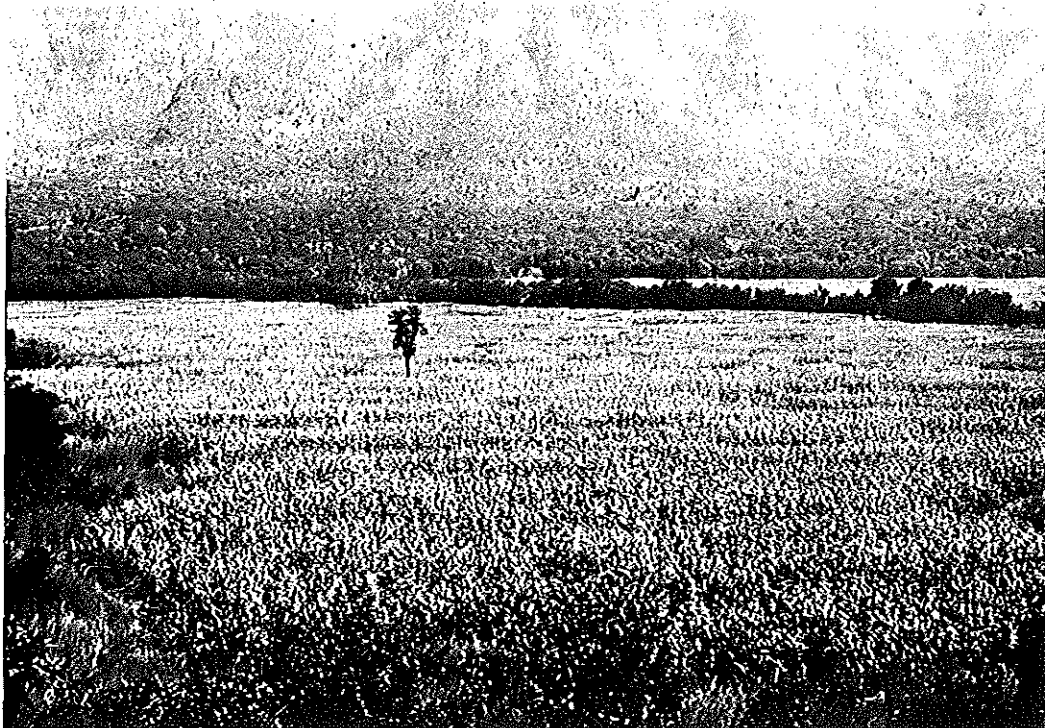


Plate - 1 Corn and Sorghum plantation scheme in the Fincha valley
(Maize grown by the state farm is in the foreground).

Transmission of trypanosomes from mammal to mammal is effected mainly by blood-sucking flies of the order Diptera. In Africa the most important biological vector of trypanosomes belong to the family - Muscidae, the sub-family Stomoxydinae and the Genus - Glossina (Wiedemann - 1830) the common name being the tsetse flies. In these flies the trypanosomes usually multiply and undergo a complex development before they are transmitted to a susceptible host. Species of tsetse may remain infective to mammals for many weeks, and one fly may pass on the infection to many animals. However, the same flies have the capacity to transmit the parasite mechanically.

There are 22 different species of tsetse flies in Africa to-day (Buxton, 1955; Mulligan 1970; Ford, 1971; FAO, 1982). Both sexes feed on blood of vertebrates, particularly of mammals (Buxton, 1955; Weitz, 1963; Mulligan, 1970; Ford, 1971).

The genus Glossina is divided into three groups (Buxton, 1955; Mulligan, 1970; Ford, 1971; FAO, 1979), namely, fusca Group (Forest tsetse), the palpalis Group (Riverine tsetse) and the morsitans Group (Savannah tsetse). The geographical distribution of species belonging to these three groups has been shown by Ford and Katondo (1977). There are certain well defined limits to the spread of tsetse flies. The northern limits generally correspond to the line where the mean annual rainfall has fallen to 78 cm and to the north of which there is drought for half of the year. Elsewhere, altitude, presumably correlated with temperature, sets a limit at 1,800 meters (Jaenson, 1978).

The Finchaa River Valley in the Abai Chomen Woreda, Horogudru Awraja, Wollega Administrative Region, was chosen as the study area, on the grounds that it was a very fertile area with immense potential for vast agricultural development.

At present there are eleven actively developing mechanised farm schemes producing over 120,000 quintals of corn and sorghum a year (see plate 1), a newly-established sugar plantation unit, and a sugar factory under construction, right in the heart of the valley. One of the largest hydro-electric-power stations in East Africa is located just below the

escarpment of the Finchaa Valley, which is within the fly belt. Moreover, new settlement programmes and additional agricultural development schemes, which are of prime importance to advance the national economy, are under-way in this area resulting in a large influx of population. The valley is also rich in other resources, with a variety of game animals, honey, timber and firewood. These attract hunters, honey and wood gatherers.

In spite of such an immense potential, the presence of a large number of tsetse flies and other biting insects in this area might have, in the past, rendered this area inhospitable to cattle and other domestic animals, human settlement and development.

With this in the background, the present study attempts to clarify matters pertaining to the identity, biology, ecology and importance of the tsetse flies of this region.

This investigation was carried out between September, 1980 and August, 1981.

2. LITERATURE REVIEW

HISTORICAL CONTEXT OF THE TSETSE AND TRYPANOSOMIASIS PROBLEM

Fossil tsetse of some 50 million years ago have been found in North America in the Miocene shales of Florissant, Colorado, although these flies are now confined to Africa south of the Sahara and to Yemen (Mulligan, 1970). The extinction of prehistoric horses and camels in North America might have been a result of tsetse-transmitted trypanosomiasis (Nash, 1969).

In 1590 travellers complained of the terrible trials which they had suffered and announced that all their horses had perished (Nash, 1969). In 1770 James Bruce of Kinnaird reported a biting insect called the 'Zimb' in Ethiopia; this could have been either a stable fly or a tsetse. In 1830 two taxonomists described two species of tsetse from specimens brought back to Europe by travellers (Nash, 1969; Buxton, 1955). Later on, in 1837, the presence of tsetse was confirmed from South Africa (Buxton, 1955). The name tsetse comes from a Botswana (Bechuana-land) word which refers to a fly destructive of cattle and is probably onomatopoeic suggesting a buzzing sound (Nash, 1969).

Explaining the tsetse problem Major Vardon wrote: "I have ridden up a hill and found tsetse' increasing at every step, till at least forty or fifty would be on my horse at once. The specimens you saw cost me one of the best of my stud. He was stung by some ten or a dozen of them, and died in twenty days" (Nash, 1969).

In 1857 another explorer, David Livingstone, lost forty three oxen because of tsetse flies. In 1864 Kirk, suspected the flies to cause a killing disease of animals. In 1880 clues to the understanding of the 'Nagana' problem were available (Ford, 1971). In 1895 tsetse flies and trypanosomes became incriminated.

In 1894, while in the Zululand, Surgeon Major Bruce, found trypanosomes in the blood of an animal suffering from nagana. Nagana is a Zulu word which signified 'a state of depressed spirits' (Nash, 1969).

Later on, in 1902, Surgeon Ford discovered a trypanosome parasite in the blood of a man (Langridge, 1976). In 1903, Castellani reported that he had found trypanosomes in the cerebro-spinal fluid of 70% of sleeping sickness cases in Uganda (Ford, 1971). The parasite was named as Trypanosoma gambiense by Patton in 1903 (Buxton, 1955; Nash, 1969; Ford, 1971). In 1909, Hearsey voiced his suspicion that there were two different types of the human disease.

In 1912 Stephens and Fantham described a trypanosome from a patient in Rhodesia and named it Trypanosoma rhodesiense (Nash, 1969; Ford, 1971).

TRYPANOSOMIASIS IN ETHIOPIA

Historical account. Trypanosomiasis in Ethiopia had been noted by early explorers and travellers, who lost their transport animals in the fly-challenge belts. In 1895 Donaldson Smith made the earliest record of Gendi (Nagana) in his transport animals which got infected while crossing the Gendi fly (tsetse) belt in southern Ethiopia (Langridge, 1976). Nine years later, Brumpt (1904) reported in the Ogaden (south east Ethiopia) one form of bovine trypanosomiasis which was called "Aino" and which was readily transmitted by Glossina longipennis.

Later on, in 1935 - 36 the Instituto Siero Vaccinogeno reported the existence of T. evansi (T. soudanense) which causes surra and T. vivax (T. cazalboui) which causes nagana. Two years later, an Italian veterinarian found bovine trypanosomiasis in Wellega Administrative Region, in the western part of Ethiopia (Langridge, 1976). Just about the middle of the 20th century, T. vivax was described in Shoa Administrative Region.

Later on, the death of cattle due to bovine trypanosomiasis was reported in Ethiopia by Bannister in 1957 (FAO, 1957). Subsequently, Peck (1959) noted the infestation of huge parts of western Ethiopia by tsetse flies and trypanosomes which denied those areas for animal husbandry. Considering the seriousness of trypanosomiasis in Ethiopia, Otte (1961) pointed out the need to destroy the vectors.

In 1962 the cattle survey in southern Ethiopia, by the Livestock Division, established that bovine trypanosomiasis had become a major cattle disease in the Omo Valley.

As far as human trypanosomiasis (sleeping sickness) was concerned, 11 cases were found in 1967 in the Gambela area during a routine investigation for malaria (Baker et al., 1970, McConnell et al., 1970). Moreover, a serious outbreak of sleeping sickness was sustained in this and surrounding areas from 1967 to 1970 (Hutchinson, 1971).

From 1971 to 1976 a survey of the distribution of tsetse fly and the prevalence of animal trypanosomiasis was conducted in Ethiopia (Langridge, 1976). According to him, out of the 14 Administrative regions 7 (Wellega, Kaffa, Gemu Goffa, Illubabor, Sidamo, Gojjam and Shoa), had both tsetse and Nagana.

Right after the survey programme, a study on tsetse and bovine trypanosomiasis control has been conducted (Ford et al., 1976).

In 1969 the joint FAO/WHO Expert committee on African Trypanosomiasis evaluated the disease and declared the immediate need for the control of the vector and the disease in Ethiopia.

Furthermore, the 1979 - WHO/FAO Technical Report series has listed Ethiopia as one of the most affected nations of Africa.

DISTRIBUTION OF IMPORTANT TRYPANOSOMES IN ETHIOPIA (after Langridge, 1976)

- a) T. vivax - This species is found in almost every part of Ethiopia.
- b) T. congolense This species is very common in Ethiopia, but not as widespread as T. vivax.
- c) T. brucei gambiense, - This species was suspected to occur amongst the Mursi people on the lower Omo about sixty years ago. Its present status in Ethiopia is not certain.
- d) T. brucei rhodesiense - This species is important in Ethiopia and was responsible for a very serious out-break of sleeping sickness in Gambela Awraja between 1967 - 1970.
- e) T. evansi - This species prevails in eastern and southeastern part of Ethiopia.

BACKGROUND ON THE TSETSE FLIES IN ETHIOPIA

Apart from this, early records of tsetse in Ethiopia have been documented by Balis and Bergeon in 1970.

According to their report, the existence of tsetse flies (G. longipennis) in Ethiopia had been recorded in 1895 by an Italian worker, based on insect collections made in 1893 by Captain Bottego along the Welmal River.

Balis and Bergeon (1970), Langridge (1976) and Ford et al. (1976), indicated the presence of six species of tsetse flies in Ethiopia. These belong to the fusca, palpalis and morsitans groups.

A. The fusca Group

Two species of this group have been recorded from Ethiopia by Langridge (1976). These are Glossina longipennis and Glossina brevipalpis.

- a) Glossina longipennis Corti, 1895.

This species was identified in 1895 from an insect collection obtained along the Welmal River in Ethiopia. It was also recorded by Peel (in Langridge 1976) in the same year in the Ogaden, around Burfurlch

and Biemuddo areas, especially along the Doghato River which is a tributary of the Wabe Shebele River. Once again, it was reported near the Juha River by Brumpt (1904) and Drake Brockman (1910) some 20 years later Ghidini (1930) reported this species to occur near Lake Abaya (L. Marguarita).

Lately, Langridge (1976) showed the existence of this species in various parts of Gamugoffa and Kaffa Administrative Regions. This has been further verified by Ford et al. (1976): lately Fuller (1978) caught G. longipennis actively biting at night.

b) Glossina brevipalpis Newstead, 1910.

The only record of this species is from the lower Omo, in the Gamugoffa Administrative Region. However, Langridge (1976) was not able to find this species from this region, or anywhere else in Ethiopia.

B. Morsitans Group

Here again two species of this group have been recorded from Ethiopia by Langridge (1976). These are Glossina pallidipes and G. Morsitans ugandensis.

a) Glossina pallidipes Austen, 1903

During the year 1936 McGridge recorded the presence of this species along the Wabe Shebele River. In 1938, Roetti also recorded its presence along the Didessa and Birbir Rivers in Wellega and along the Akobo River in Illubabor. In 1956 Ovazza found G. pallidipes along the Gojeb River in Keffa. Recently, Langridge (1976) showed the wide distribution of the species in Gamugoffa, Kaffa, Shoa and Illubabor Administration regions. Ford et al. (1976) have showed the distribution of this species in Ethiopia. Fuller (1978) also collected G. pallidipes from the southern part of Ethiopia.

b) Glossina morsitans ugandensis Vander plank.

G. morsitans was first recorded by the Italian investigator Di domazzo in the Didessa Valley in the Wellega Administrative Region and near Lake Awassa in the Arusi and Sidamo Administrative regions in 1937. The same

year Roetti found it along the Birbir, Chibise and Berber-Uaha River in Wellega and Kaffa and on the Akobo River along the Sudan border in Illubabor. In 1938, Caccavella confirmed the existence of this species in Awassa (Balis and Bergeon, 1966; Langridge, 1976).

Later work by Balis and Bergeon (1966), Langridge (1976) and Fuller (1978), indicated the existence of this species in various parts of Gojjam, Sidamo Shoa, Wellega, Kaffa, Illubabor and Gamu Gofa Administrative Regions.

c) Palpalis Group

Langridge (1976) also recorded two species of the group from Ethiopia. These are Glossina tachinoides and Glossina fuscipes fuscipes.

a) Glossina tachinoides westwood, 1850.

In 1939 Ghidini recorded this species on the Baro and Gilo River in Illubabor Administrative regions.

In 1956 Ovazza also found this species in Illubabor but along another river, the Akobo. Langridge (1976) mentioned that Balis and Bergeon (1970) had recorded this species from Didessa in the Wellega Administrative region.

Furthermore, one male fly had been found near Wanago Village near Della in the Sidamo Administrative Region. The species was also recorded on the Jakau River in the Illubabor Administrative Region.

b) Glossina fuscipes fuscipes Newstead, 1910.

This species was first recorded by Brumpt in 1910 from the lower Omo river. In 1937 Ghidini found this species around L. Awassa in Sidamo and also on the tributaries of the Akobo River in Illubabor. Furthermore, in 1938 Roetti found it along the Didessa River in Wellega and Birbir River in Illubabor. Later on, Ovazza (1956) found this species on the Ghibi (Upper Omo) River.

According to Langridge (1976), Balis and Bergeon (1970) and Fuller (1979), this species has been recorded around various rivers and streams in Gamu Goffa, Sidamo, Wellega, Kaffa and Shoa Administrative Regions.

CLASSIFICATION AND BIOLOGY OF TSETSE FLIES.

The genus Glossina is divided into three groups (Newstead, 1911).

These are 1) the fuscus Group 2) the palpalis Group, and 3) the morsitans Group, each group is further divided as follows (Buxton, 1955; MacLennan, 1975; FAO, 1982).

The fuscus group is mainly restricted to west Africa where as certain species of the palpalis and the morsitans Groups are of importance in the transmission of human and animal trypanosomiasis in East Africa including Ethiopia.

LIFE CYCLE OF TSETSE FLIES

The life-cycle of all tsetse species is basically similar (Buxton, 1955). After a successful mating, which usually takes place within the first week of life and need not occur again thereafter, the female stores a supply of sperm which is used to fertilize the eggs as they are produced. The eggs are produced singly at intervals of about ten days. Each egg hatches in the uterus where larval development and maturation occur before the next ovulation.

On completion of its development, the larva is deposited on a suitable substrate (eg. in loose soil under rocks, logs or trees) and quickly buries itself to a depth of 20 - 30 mm. This form of larviparous reproduction, as opposed to the oviparous method, is an unusual feature confined to a minority of insects of which the tsetse is one. This means that the potential population growth rates of tsetse flies are relatively low. Pupation occurs almost immediately after burial and subsequent metamorphosis takes place during the following four to five weeks, when the adult fly emerges. The timing of all these events is variable and strongly temperature-dependent. The newly emerged fly, which will feed exclusively on vertebrate blood, takes its first meal within four days and must continue to feed every few days for the rest of its life. Under laboratory conditions, female tsetse may live up to five months but in the wild, the natural span is unlikely to be more than three months. It is probable that male flies do not survive as long as this.

LIFE CYCLE OF TRYPANOSOMES IN TSETSE FLIES

In infected flies, the trypanosomes ingested with the blood-meal undertake a cycle of development. They perform a series of morphological changes, before assuming a form known as the epimastigote. Eventually these give rise to

metacyclic trypanastigote forms, which infect the vertebrate host. Metacyclic forms eventually enter the mouthparts or salivary glands and from here get inoculated into the vertebrate host when the fly feeds (Mulligan, 1970, Hoare, 1970, Putt et al., 1980).

The development cycle of the trypanosomes within the tsetse fly varies according to the different sub-genera of trypanosomes. The simplest development cycle occurs in the subgenus Duttonella which includes Trypanosoma vivax and Trypanosoma uniforme.

In the subgenus Duttonella, the trypanosomes ingested with the blood-meal attach themselves to the wall of the fly's proboscis; here they develop into the epimastigote form, before invading the hypopharynx and developing into the infective metacyclic form. Trypanosomes which fails to become attached to the proboscis pass into the mid-gut and are digested.

In the case of the sub-genus Trypanozoon which includes T. brucei, T. rhodesiense and T. gambiense, the trypanosomes upon ingestion go into the endoperitrophic space of the mid-gut, an area which extends from the cardia (proventriculus) to the hind gut. The parasites then go behind the free end of the peritrophic membrane and enter the ectoperitrophic space where they multiply: From here they travel forward into the proventriculus. At this region they penetrate the thin peritrophic membrane and re-enter the endoperitrophic space. The parasites move further anteriorly into the esophagus, the pharynx and the tip of the hypopharynx through which they gain access into the salivary glands. Here the trypanastigotes first develop to epimastigotes and eventually to metatrypanosomes.

In some instances, Trypanozoon trypanosomes do not complete their life cycle and may disappear spontaneously or appear incapable of invading the salivary glands (Putt et al., 1980).

Development of the trypanosomes of the sub-genus Nannomonas, namely T. congolense and T. simiae, follow much the same sequence in the fore - and mid - gut regions as that of the sub-genus Trypanozoon. However, trypanosomes of the subgenus Nannomonas do not finally enter the salivary glands but become attached to the walls of the proboscis and develop first to the epimastigote stage and later to the infective metatrypanosome stage (Mulligan, 1970; Putt et al., 1980; Hoare, 1964). The classification of the mammalian trypanosomes in Africa was given by Mulligan (1970) and Hoare (1970).

FACTORS AFFECTING THE DISTRIBUTION OF VECTORS

Three main factors affect the distribution of vectors. These are temperature, moisture and food.

A. Temperature

As stated by Andrewartha and Birch (1954), many poikilothermous animals have sigmoid temperature - development curves. As a result, development slows down at higher temperatures and increase in temperature is not positively co-related with fly capture (Glasgow, 1963). At about 35°C development starts to slow down in Glossina.

The relationship between pupal development and temperature was explained by Bursell (1960) and also vividly stated by Glasgow (1963). According to them the relation between temperature and the duration of pupal development is not the same as the relation between temperature and metabolic rate. This is crucial in that the energy for metabolism is provided from the fat already stored; this fat supply cannot be replenished until the emerged adult obtains its first meal.

It was further clarified by Glasgow (1963) that the duration of development and metabolic rate seem to be in balance at 22°C - 24°C and the emerging adults begin their free life with maximal reserves of fat. Moreover, the interval between larviposition and emergence is 31 days at 24°C. From this the interval at other temperatures can be calculated by the formula $\frac{1}{0.0323} - \frac{1}{0.0028 (+24)}$ where t is the mean temperature of maintenance (Jackson, 1949; Glasgow, 1963). At lower temperatures the speed of development is related more to the speed of fat consumption, in other words, a long development period requires higher fat consumption. By the time the adults emerge, they have less fat left in them. At 14°C, which is the lower threshold for successful development, the fat is readily consumed before development is completed (Glasgow, 1967). Conversely, at higher temperatures, the speed of fat consumption is accelerated more than the speed of development. Thus if it is too hot, the fat reserves are exhausted before development is complete.

Nash (1942) studied the distribution of puparia the correct word is pupiparium of G. morsitans submorsitans in a 'residual forest island' in northern Nigeria. He observed that during the cold season (in December) puparial development took about 45 days in the ground and was confined to the edge of the forest. In January small numbers were found in the centre of the islands, and by April they had almost disappeared from the edge and had concentrated largely in the centre. In the meantime, the soil temperature had risen from 18°C to 28°C in the centre, with 23 days of developmental period in the ground. At the edge of the island the temperature had risen from 18°C to 29°C providing 22 days of developmental period. From this it is possible to take temperature as a limiting factor in the distribution of tsetse flies (Glasgow, 1963). This was also realised by Nash (1942), as the temperature at the edge of the forest was so high that a substantial proportion of the puparia exhausted their fat reserves and died before they were able to emerge.

Puparia which began life in the centre of the forest may complete development in the cooler conditions without any serious losses when compared with those at the edge (Nash, 1942). Thus by depositing pupae in the centre of the forest island, these flies saved their own lives and those of their offspring. Probably this was the reason for the move (Nash, 1942; Buxton 1955). The actual stimulus which caused the individual flies to move into the centre was, however, the negative phototaxis operating at temperatures above 30 - 32°C.

Another effect of temperature has been mentioned by Nash (1937) and cited by Glasgow (1963). The former stated that G. tachinoides were most active at about 29°C. From October to February the mean maximum temperature in the habitat of this species was 28°C - 31°C, and during this season maximum catches were made in the middle of the day, when temperature was highest. In March, April and May the maximum temperature was about 36°C. During this hot season the highest catches were made early in the morning and late in the afternoon, the fly being inert at midday. Smaller catches of G. morsitans submorsitans appeared to show the same cycle, but less clearly.

At extremely high temperatures, one could not determine whether adults or puparia are affected (Glasgow, 1963). However, Kondrew (1953) cited by Glasgow (1963) suggested that it is the effect of the cold on the puparia

rather than on adults which limits the distribution of Glossina in Southern (Zimbabwe) Rhodesia. Apart from this, the upper altitudinal limit should be taken into consideration, since during the cool season the flies are known to be inactive (Jackson, 1955). On the other hand Bursell (1960), mentioned instances in East Africa where in mixed fly-belts the larger species tolerated the altitude, which suggested that it was the effect of a low mean temperature on puparia which was critical.

In general terms, it seems that in the life cycle of Glossina no particular stage of development is susceptible to temperature (Glasgow, 1963; Mulligan, 1970; Ford, 1971). If temperatures are high and approach the lethal values to adults, successful completion of development of the puparia in the soil is out of the question. When temperatures are extremely low, and when the period of diel activity is severely limited, again the mean temperature is likely to inhibit the puparial development (see Glasgow, in Mulligan, 1970).

B. MOISTURE

Bursell (1958) studied the water-balance of the immature stages of tsetse flies. For a better understanding of this subject the development of the puparia in the soil is of paramount importance (Glasgow, 1967). The large larva which is deposited by the mother fly is in fact a third instar larva. It is the integument of the third instar larva which becomes rigid and darkens to form the puparial shell. At this time water can be lost through the polypneustic lobes, which are connected with the inner tracheal system within the puparial shell. At 25°C the third instar moults to the fourth instar in one day. According to Bursell (1958), during moulting the third instar larva is first retracted from the inner surface of the puparium and the tenuous integument of the fourth instar. The tracheal system is still connected with the polypneustic lobes, and the gut of the third instar larva is connected to the exterior surface of the puparium by way of the third instar anus. At this stage water can be lost through the polypneustic lobes and through the general integument. Any moisture getting into the space between the fourth instar integument and the puparial shell must first diffuse through the puparial shell before it is lost to the system. Water can be lost by excretion through the anus, but this loss is under active control. If the

third instar has been kept in moist air, losses from excretion are relatively high in the fourth instar, but the reverse would hold true if the old instar is kept in dry air (Bursell, 1958; Glasgow, 1963). In Glossina morsitans morsitans, the mechanism completely compensates water losses at humidities of between 40 percent, and 100 percent. Within these limits the water content at the time of pupation is constant (Glasgow, 1963). But at humidities below 40 percent, more water is lost by transpiration than is excreted; compensation is therefore incomplete and the water content is reduced to a subnormal level (Bursell, 1955). The fourth instar lasts about four days, meaning that the true pupa actually appears five days after the formation of the puparium. There are two possible routes for the escape of water from the puparium. These are the integument and spiracles. Spiracular losses are under control. Therefore less water is lost from an individual (3rd or 4th stage) that has been previously exposed to low humidities than from one exposed to high humidities (see Bursell in Glasgow, 1963).

Bursell (1960) examined the various ways in which this resistance to dessication could have developed. He found that the active mechanisms, i.e., excretory regulation and spiracular regulation, could not be responsible, since they are well-developed in both susceptible and resistant species. Finally, mere size is advantageous (Mulligan, 1970). G. longipennis weigh more than 4 times as much as G. austeni, but the surface area of the puparium is less than 3 times that of the latter. Thus, even with equal permeabilities, a species the size of G. longipennis would be considerably more resistant than one the size of G. austeni (Glasgow, 1963). In some species resistance to dessication is attributed to the puparial shell and size of the pupa of tsetse flies.

Some species of Glossina suffer heavy mortality if the puparia are exposed to a relative humidity of less than 30% while others tolerate completely dry conditions. (Glasgow, 1963) is of the opinion that water-proofing seems too important to be dismissed so lightly, even if sufficient evidence is not available. He, therefore, proposed to leave the matter open.

On the other hand, the water proofing of various species, in relation to their habitat, would not be of value if the tsetse puparia are localized in areas where the humidity is close to saturation (Glasgow, 1963).

Buxton (1955) stated that the atmosphere of the soil spaces may be very nearly saturated even when the soil is apparently dry.

Jackson (1945) carried out field experiments which led him to support the hypothesis that pupal water balance would be a limiting factor in the occupation of dry environments.

An adult emerging from the pupa may take 3 or more days before it takes its first blood meal. The fat and water reserve at this stage is dependent on the reserves it brings forward from the pupal stage (Mulligan, 1970).

If a teneral fly is kept starved at a relative humidity of 80 percent, it will soon die, after exhausting its fat. On the other hand, if this fly is kept at 0% R.H. it will die of dessication even if it has substantial reserves of fat (Bursell, 1957a & 1970). Therefore, a tsetse must feed within a very few days of emergence; if it fails to do so it will die. The immediate cause of death may be shortage of fat or shortage of water (Glasgow, 1963). A resting teneral fly could control the rate of water loss from the body by closing the spiracles to some extent; the governing factor is the actual ambient humidity (Glasgow, 1963). Comparing flies in flight and at rest, Bursell (1963) found that in flight the oxygen consumption increased by a factor of 22, but water loss increased by a factor of only 6. Thus, other things being equal, in 24 hrs. a tsetse which flew for 35 minutes would lose as much water as a resting fly would in 26.9 hrs. The corresponding fat consumption would be the equivalent of 36.8 hrs. resting consumption (Bursell, 1960)

In the case of non-teneral flies the main source of water is obtained from the blood meal. As shown by Glasgow (1963), atmospheric humidity is not so important for adult tsetse flies. This view is, however, in contradiction to works of Nash (1933) and Jackson (1948).

C. Food

Tsetse flies are known to feed on a wide variety of vertebrate hosts. Some examples of the hosts include bushpig, bushbuck, warthogs, rhinoceros, elephant, buffalo, hippopotamus, giraffe and gazelle (Glasgow, 1963). Host

selection mechanisms are also variable and species-dependent (Glasgow, 1963; Mulligan, 1970; Ford, 1971, Put, et al 1980; Onyiah, 1980).

3 - STUDY AREA

3.1 Geography

The Finchaa River Valley is in the western part of Ethiopia, in the Wellega administrative district, latitude $9^{\circ}9'N$ and longitude $36^{\circ}75'E$ (see MAP 1). Finchaa is actually some 285 kms west of Addis Ababa. The valley is estimated to cover 2,000 sq. kms. of land. The altitude of the valley ranges from 1600 m to 2200 m above sea level. The slope in the valley has an average gradient of 1:20. The Finchaa river passes between Horo Gudru and empties into the Abay River (the Blue Nile).

As a result of the sharp drop in altitude, the vegetation of the area shows significant altitudinal zonation.

The fly sampling area starts at an altitude of 1980 m above sea level where the tsetse flies are commonly found and descends to 1680 m (Fig 1; plate 2 and 3).

3.2 Climate

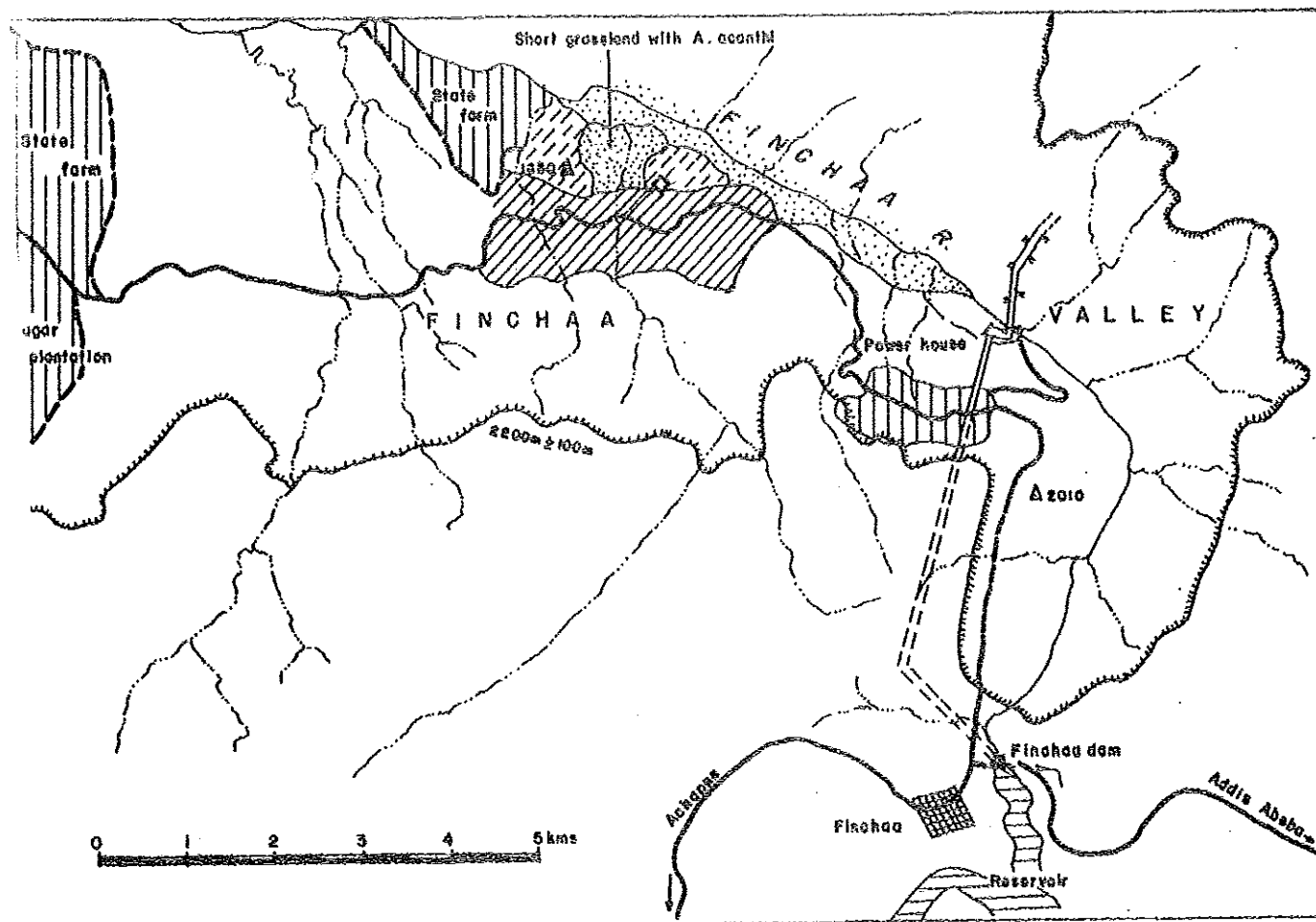
The mean monthly temperature of the valley is $31.37^{\circ}C$, the mean monthly percent relative humidity is 49.76 and the mean monthly rainfall is 3.36. The big rainy season is in June, July and August and the little rainy season is in April. The hot dry season extends from December up to March.

3.3 Vegetation and Macrovertebrates

The study area has been divided into five distinct zones based on the types of vegetation that are encountered (Table 1).

Zone five is open grassland without woody vegetation. The grasses consist of Andropogon sp., Chloris sp., Hyperrhenia sp. and Pennisetum sp. The area is temporarily water logged during the rainy season, making it unfavourable for trees.

FINCHAA VALLEY



LEGEND

- River (seasonal)
- Cliff (escarpment)
- Road
- Track
- Elevation in meters
- Farm boundary
- Water pipe in tunnel
- Road in tunnel
- Power lines to Addis Ababa
- Si-conical trap
- Thick riverine forest (dominated by Ficus)
- Wood land savana
- Open grass land
- Open wood land savana
- Thick riverine forest
- Short grass with Acoxia

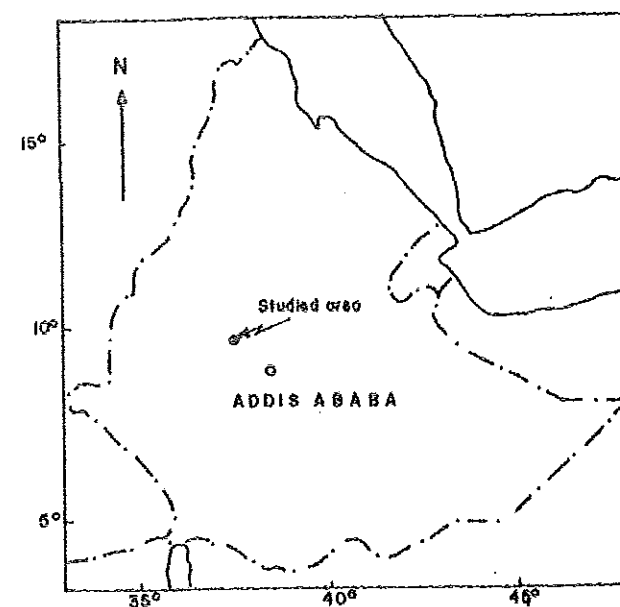




Plate 2 - Aerial photo of the Fincha River Valley

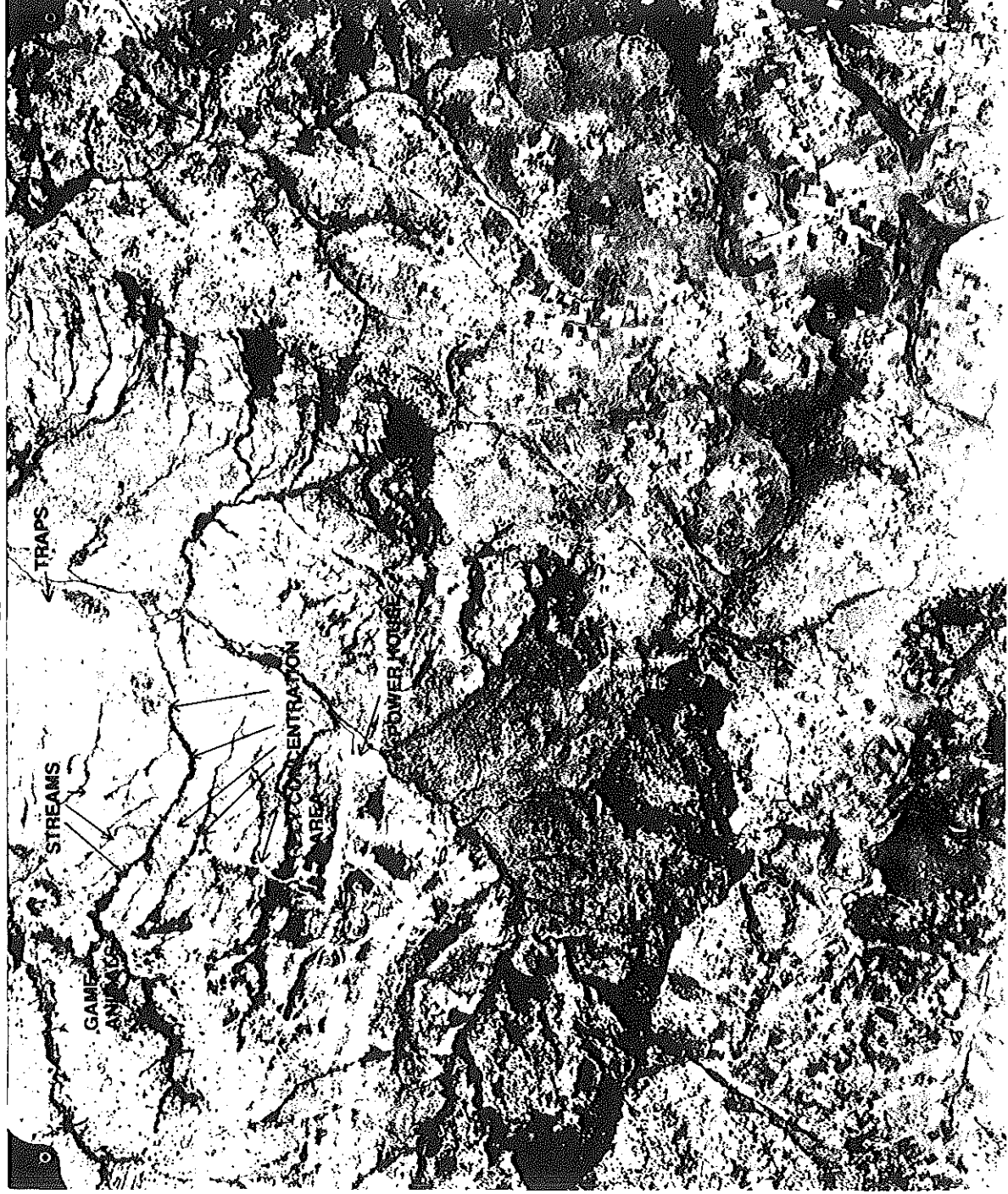


Plate 3 - Aerial photo of the Finchaa River Valley

Bush fires are common in zones three, four and five. Zones three and five are the zones most affected by the fire, as these areas are largely covered by grasses and herbs.

TABLE - 1 - THE FIVE VEGETATION ZONES OF THE FINCHAA RIVER VALLEY.

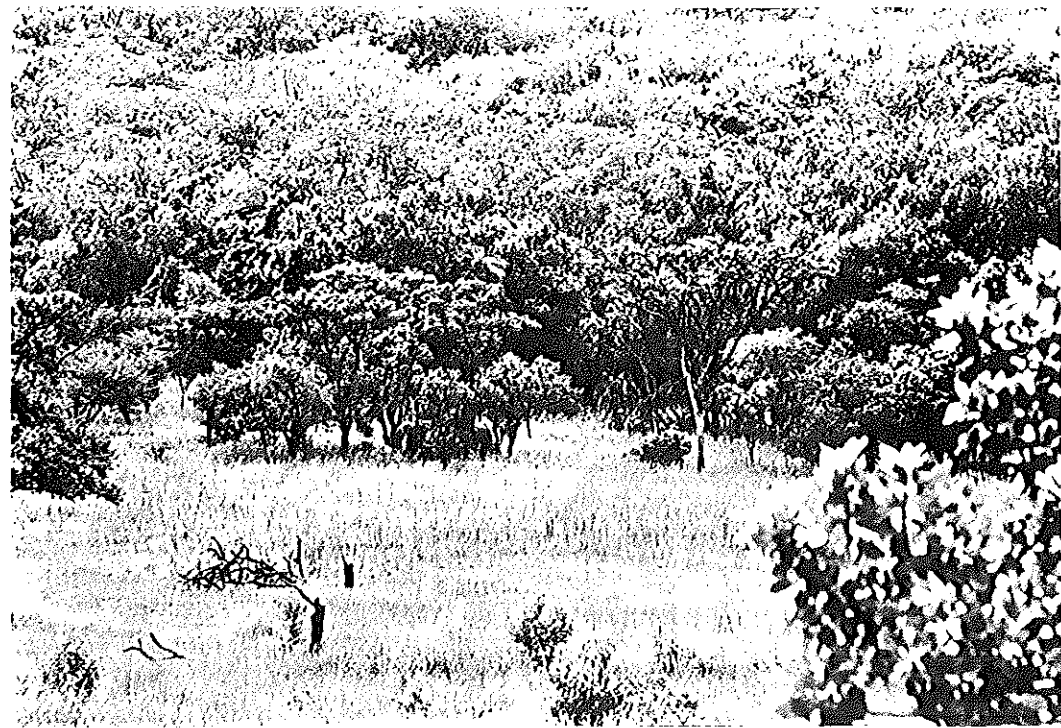
	Horizontal Distance	Type of veg.	Composition of veg.
Zone I	2 kms	Thick riverine forest	Podocarpus gracilior Ficus cycomorus entada sp. Chroton machrostachyus Pygium africanum Phoenix reclinata Syzigium geuneense Alcophyles africanus Cordia africana Acanthus eminens Phragmites sp. Ocimum suave Polygonum rupestris
Zone II	2 kms	Open wood - land	Terminalia brownei Cumbretum glaucescens Cassia singuana Sterculia sp. Cussonia sp. Stereospermum kunthianum Pleostigma toningii Oxytenaria sp. Grewia bicolor Zephyrus spinichristi Solanum incanum Bidens sp. Hyperbaena sp.
Zone III	2 kms	Woody grass land	Grewia bicolor Maytenus sp. Securidaca longipedunculata Oxytenaria sp. Terminalia brownei Cumbretum glaucescens Polistigma toningii Cassia singuana Gardenia lutea Acacia seyal Hyperbaena sp.

Refestation

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Zone II	2 kms	Open wood - land	Terminalia browenii Cumbritum glaucesceus Cassia singuana Sterculia sp. Cussonia sp Stereospermum Kuntainum Pleostigona toningii Oxytenaria sp. Grewia bicolor Zezyphus spinichristi Solanum incanum Bidens sp. Hyperrahenia sp.
Zone III	2 kms	Woody grass land	Grewia bicolar Maytenus sp. Securidaca longipedunculata Oxytenaria sp. Terminalia browenii Cumbretum glauscens Polistigma toningii Cassia singuana Gardenia lutia Acacia seyal Hyperrahenia sp.



(B)

Plate 4 - Zone IV (A) and (B) Zone V in the Finchaa valley (foreground only)

Table - con't

	Horizontal Distance	Type of Veg.	Composition of Veg.
Zone IV	2 kms	Cumbretum grass-land	Terminalia brownii Anogesius leocarpa Cumbretum glanscens Cassia singuana Acacia sieberiana Gardenia lutia
Zone V	2 kms	Open grassland	Andropogon sp. Chloris sp. Hyperrhenia sp. Pennisetum sp.

The Finchaa hydro-electric power station, the eleven mechanized farm units and the Finchaa sugar factory project and the sugar plantation estate are all found in this valley and close to the study area (Map 1). Moreover, over 2,000 people live on the state farm schemes and an additional three hundred work at the Finchaa sugar factory project and on other plantations.

It is important to note that most of the people who work in the various projects often move up from the valley to Fincha town on the escarpment, either for work or for weekly shopping.

On the edges of the escarpment (about 2200 m.) infected cattle are found and the risk of infection may be very high in such places. However, as one goes down the valley one can hardly find any live-stock: on the contrary, wild animals are abundant.

From my own observation and from interviews I had with local people who live and worked in the valley for years, the following are the most common animals (Table 2 and Plate 3).

Table (2) - Types of animals that are expected to be found in the Fincha Valley

English	Scientific Name	Remarks
Warthog	Phacochoerus aethiopicus	
Duiker	Cephalopus sp.	
Jackal	Canis aureus	
Colobus monkey	Colobus abyssinicus	
Francolin	Francolinus sp.	
Guinea Fowl	Numida meleagris macroceras	
Civet	Viverra civetta	
Porcupine	Hystrix sp.	
Hyrax	Procavia capensis	
Lion	Panthera Leo	
Leopard	Panthera pardus	
Abyssinian Hare	Lepus habessinicus	
Anubis baboon	Papio anubis	
Blue monkey	Cercopithecus mitis	
Bush Buck	Tragelaphus scriptus	
Greater Kudu	Tragelaphus strepsiceros	
Bush Pig	Potamochoerus Porcus	
Wild dog	Lycan pictus	

4 - MATERIALS AND METHODS

4.1 Tsetse Sampling

In the present study, tsetse population sampling was carried out every month for a period of seven days using Biconical traps (Challier and Laveissiere, 1973), the Screen/Hand net and the Vehicle Patrol methods (Buxton, 1955; Mulligan, 1970; FAO, 1982). These observations were made for a total of 12 months starting from September, 1980 to August, 1981.



(A)



(B)

Plate 5 - Photographs of vervet monkey (A) and the skin of Crocodile (B) taken in the Finchaa valley during the study period

4.11 The Biconical Traps

The Biconical trap is based on the original model described by Challier and Laveissiere (loc. cit) with the change of colour recommended by Challier et al. (1977). The trap consists of an upper cone of nylon mosquito netting made of four segments sewn together; a lower cone of blue cloth canvas also consisting of four triangles, in each of which an opening is made; within are two screens of black cloth sewn together to form a cross and placed inside the trap and a metal rod extending along the centre (Fig. 2 and Plate 6).

The two cones are sewn together, base to base, around a loop of galvanized iron wire to produce a cavity within which the black screens form the boundaries of four sectors. There is an opening in the lower cone for each sector, by which the tsetse flies are able to enter. The trap is held in place by the metal rod, which passes through the sleeve produced by the two vertical seams of the black screens.

Twenty six traps were set along a transect 2.6 kms. long which ran parallel to the Finchaa river and was some 200 meters away from it.

The traps were placed at 100 m. intervals. The transect passes through wooded forest, open savannah woodland and savannah grassland (see Map 1), at an altitude of approximately 1680 meters.

Captures were recorded daily from 09:00 hrs. to 14:00 hrs. for three consecutive days at monthly intervals.

4.12 The Screen/Hand Net Method

Tsetse flies were also sampled using the Screen/Hand net method on a fly round. The flies were attracted to the deep black colour of the screen and to the movement of the fly catching party (Mulligan, 1970). The Screen was a piece of black cotton cloth and the hand net was made of cloth netting on a suitable frame as shown in Plate 5.

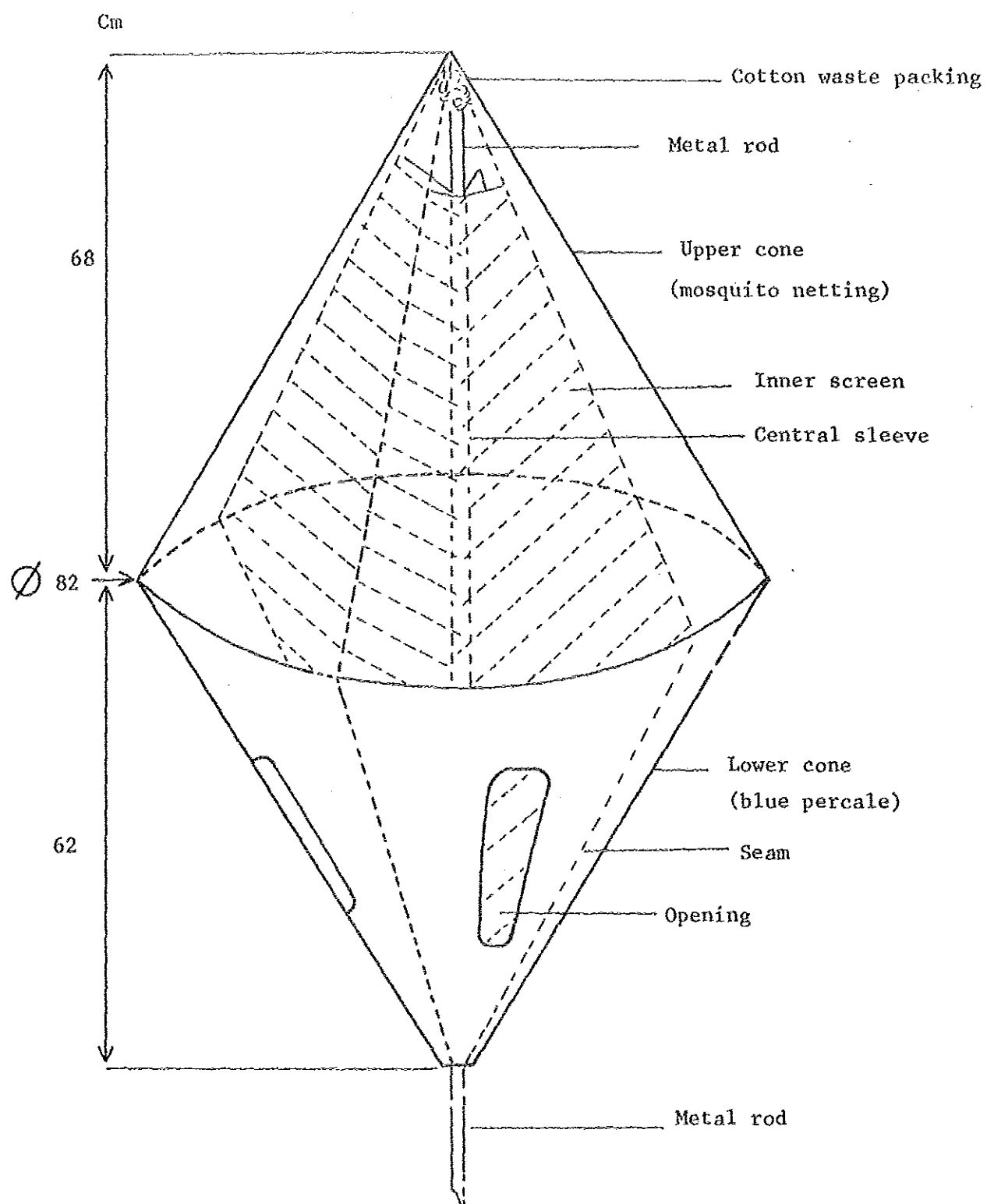
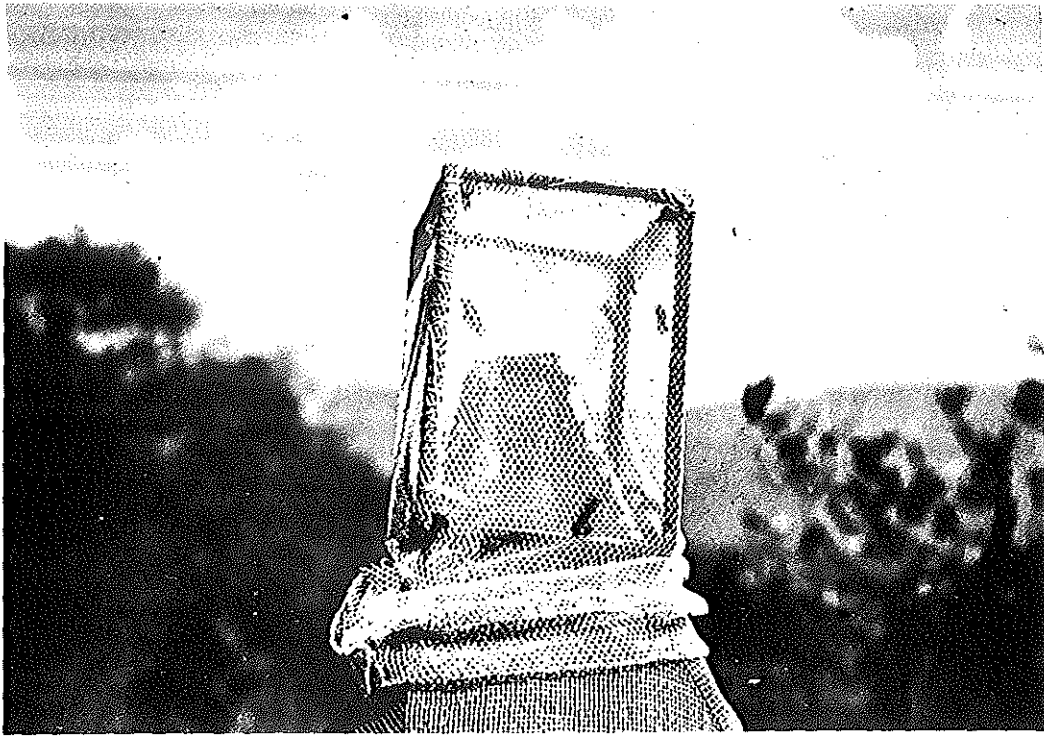
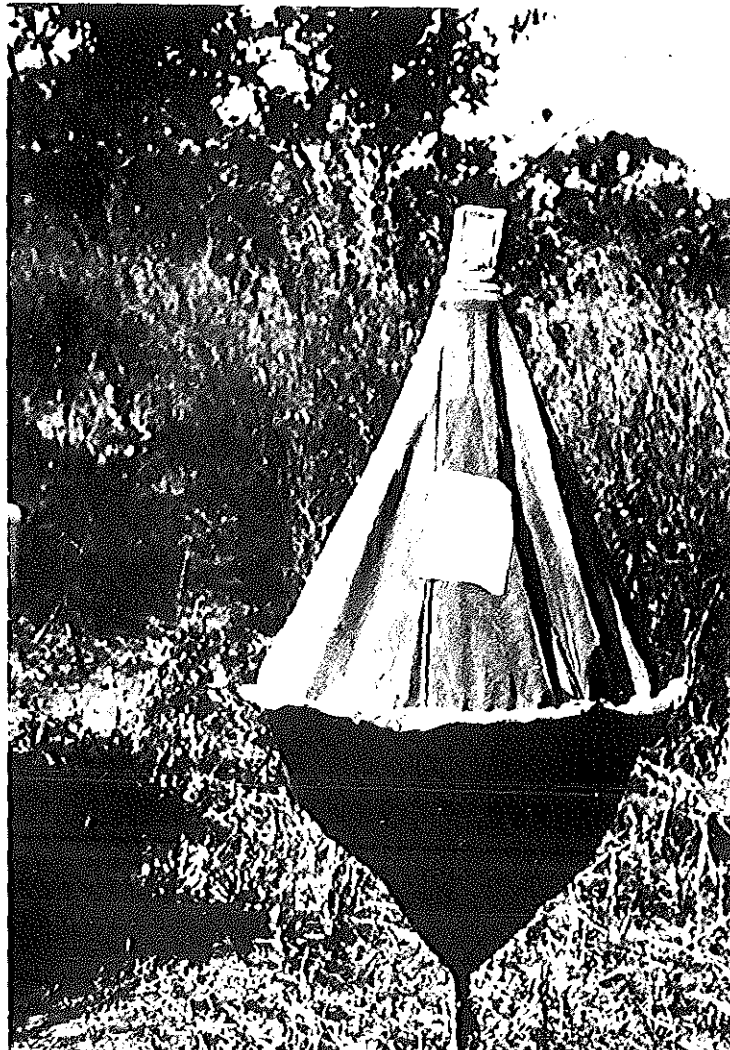


Figure 2 : Diagram showing the various parts of the Biconical Traps.



(B)



(A)



(B)

Plate 7 - Photographs showing the vehicle patrol (A) and Screen/Hand net (B) methods of sampling in the Finchaa river valley

The black screen measuring 90 cm x 90 cm was tied to a pole that was carried on the shoulders of two people who stopped at 100m intervals for 5 mins. A person holding a hand net followed the screen party in order to collect the tsetse that came to rest on the black screen. Flies collected by this method were immediately transferred into cages or test tubes for on-the-spot or later identification.

The fly round was carried out along a 4.8 kms. path, along which a total of 48 fixed catching stops were marked. The path extended from the base of the escarpment at 1980 m to the open grassland area where the Biconical traps were placed (Map 1), altitude 1680 m.

4.1.3 THE VEHICLE PATROL METHOD

A vehicle at a speed of about 15 km/hr attracts adult flies (Buxton, 1955; Mulligan, 1970; FAO, 1982). In the present study a Nissan Patrol was driven at about 15 km/hr along the fly-round path that was used for the Screen/Hand net sampling method. The number of stops (48) and the intervals between them ($\pm$ 100m) were also similar. The windows of the vehicle were kept open while it is in motion, but immediately closed at each stop to prevent escape of flies, as well as to allow collection of those that have entered the vehicle (Plate 5). Including the driver, 4 persons used to sit in the vehicle to catch the flies with plastic test tubes.

5 minutes were spent at each stop and catches were recorded from 09:00 to 14:00 hrs and fly sampling were done over three consecutive days.

Fly catches were recorded from 09:00 to 14:00 hrs. for a single day.

4.2 WEATHER RECORDING STATION

A weather recording station was set up at 1680 m. above sea level, close to the hydro-electric power station for the period between September, 1980 to August, 1981. The most important weather elements which were believed to have a substantial influence on fly activity were recorded (Ford, 1970; FAO, 1982). These included daily air temperatures relative humidities, wind speed and rainfall. The data for rainfall were obtained from the weather recording station of the Finchaa. Sugar factory project situated about 20 kms from the study area and at an altitude of 1500 m. above sea level.

4.2.1 Relative Humidity

The relative humidity was measured using a recording thermohydro(baro)graph, a simple portable relative humidity meter, and a wet and dry bulb thermometer. The thermohydrograph and the other instruments were read once a time.

4.2.2. Air Temperature

Temperatures were recorded by means of a recording thermohydrograph, an ordinary thermometer and a minimum and maximum thermometer, recording was the same as for relative humidity.

4.2.3 Rainfall and Wind Speed

A rain-guage and an anemometer were employed to determine the amount of rainfall and the wind - speed and direction in the study area. Records were taken once a day at 11:00 a.m.

4.3 Identification of Tsetse Flies

The identification of tsetse flies of the Finchaa valley was done using Buxton (1955) and FAO (1982). Among the major characteristics used in the identification of the flies to the species level were:

- a) the dark ring on the fourth tarsal segment of the front leg.
- b) the dark last two tarsal segments of the front leg, and
- c) the dark last two tarsal segments of the hind leg.

The sub-species level of identification was done by examination of the male genitalia.

4.4 Apparent Density

The apparent density of Glossina morsitans ugandensis based on the number of non-teneral male flies collected per 10,000 yards (= m) was determined for a period of one year, using the Vehicle Patrol and Screen/Hand net methods. Due to the delays in acquisition of the Biocnical traps, observations with this method were limited to eight months (January to August, 1981).

The formula used to calculate the apparent density of tsetse flies of a given area using the vehicle Patrol and Screen/Hand net methods was that of Buxton (1955).

$$\text{Apparent Density} = \frac{\text{No. of Non-teneral male flies}}{10,000 \text{ Yards}}$$

The formula used for the Biconical traps was that of Challier (1980).

$$\text{Apparent Density} = \frac{\text{No. of Non-teneral flies}}{10 \text{ hrs.}}$$

4.5 AGE DETERMINATION AND PHYSIOLOGICAL CONDITION OF TSETSE FLIES.

4.5.1 Wing-fray Method

Jackson's (1946) method of mean age determination of male tsetse flies by their wing frays was employed in the present study.

Males collected by the three sampling methods had their wings removed from the rest of the body and examined under the stereoscopic dissecting microscope. The wings were compared with standard wing fray charts Jackson 1946.

4.5.2 Ovarian Aging

Female flies collected by the Biconical traps were first washed in 2% detergent and later dissected in saline solution under a stereoscopic dissection microscope. Dissection was carried out using Challier (1965) and Saunders' (1962) methods. Exposed ovaries were then compared with standard age determination charts and tables of Challier (1965) and Saunders (1962).

4.5.3 Abdominal Appearance (Hunger Category)

Hunger category of flies (i.e. engorged - I, Replete - II, intermediate - III, and Hungry - IV) was determined by observing the abdomen of the flies collected. This was done by confining each individual fly in a test tube. The hunger category of the tsetse flies collected by different methods were determined by comparing the present observation with standard diagrams (Mulligan, 1970; FAO, 1982).

4.6 DETERMINATION OF NATURAL HOSTS OF TSETSE FLIES

Blood - engorged flies collected by the Biconical traps were dissected under a stereoscopic dissecting microscope in a dry petri-dish. The blood was removed from the gut and smeared on a whatman filter paper No. 1. This was later allowed to dry in a dessicator overnight. Several samples were then mailed for identification by precipitin test to Dr. Killick-Kendrick, Imperial College of Science and Technology Field station, Silwood Park, Sunninghill, Ascot, Berks, England.

4.7 INFECTION RATE DETERMINATION

A sample of non-teneral flies were first killed by crushing the thorax. They were then washed in 2% detergent-saline and later put in a large drop of clean saline on a slide. Legs and wings were removed. Gentle forward traction on the head pulled out the salivary glands from the rest of the body. Using fine needles, the proboscis was removed from head capsule by levering the basal bulb away from the head and it is unzipped. The various components of the mouth parts (i.e hypopharynx labium etc.) were separated the hypopharynx was examined for trypanosomes. The salivary glands were later drawn through and the head capsule then discarded. The two glands were mounted on a slide in saline. After adding a cover-slip the glands were examined under the microscope (X40 objective) to detect possible trypanosome infections.

Ultimately, the abdomen and thorax is placed with the dorsal side up wards, and by nicking the abdominal integument on either side at the posterior end and using needles or forceps the tip of the abdomen is pulled gently to withdraw the gut.

The midgut was later separately withdrawn and examined under a compound microscope and examined for the presence of trypanosomes. Different species of trypanosomes are localized in different organs of the insect. For instance, T. vivax is found in the proboscis, T. Congolense in the probos and midgut and T. brucei in the probos salivary glands and midgut

5. RESULTS

Nine major factors were observed and studied during a year round investigation of the tsetse flies of the Finchaa River Valley. Each factor will be treated below in numerical order.

5.1 Species Composition

Identification of a total of 10,000 adult tsetse flies collected between September 1980 and August 1981 using the Biconical Traps, the Vehicle Patrol and the Screen/Hand net methods, showed that only one species, Glossina morsitans ugandensis, was present in the Finchaa River Valley.

5.2 Altitudinal Distribution

The altitudinal distribution of the tsetse flies of the Finchaa River Valley was studied using only the Screen/Hand net method and the Vehicle Patrol method (Tables 4 and 5). Both methods indicated that in this area tsetse prevailed in altitude ranges of 1650 to 1980 meters (Figs 3 and 4).

This study also revealed that the numbers of tsetse flies caught decreased as the altitude increased. Throughout the period of investigation more males than females were collected at different altitudes. The difference in the number of the 2 sexes collected at each altitudinal range varied and became significant as the altitude decreased (Table 3).

Table 3 Chi - Square value^{1/} for the sex distribution of Glossina morssitans ugandensis collected by Vehicle Patrol and screen/hand net methods at different altitudinal ranges.

Altitude Range (in meters)	Chi-Square	Significance Level at 1 d. f
1650 - 1700	197.78	Significant
1701 - 1750	9.595	"
1751 - 1800	4.019	"
1801 - 1850	0.5635	No significant
1851 - 1900	0.7350	"
1901 - 1950	1.4425	"

^{1/} Calculation was done using contingency table with Yates, correction (1960)

$$\frac{N \left[\left| \frac{AD}{(A+B)(A+C)} - \frac{BC}{(B+C)(B+D)} \right| - \frac{1}{2N} \right]^2}{1}$$

Table - 4 - Altitudinal distribution of Flies using S/H method from September 1980 to August 1981.

Months/year	Altitude	Species	Teneral	Non - Teneral				M	F	Total	
				Hunger category							
				I	II	III	IV				
September 1980/1650 - 1700	(A)	G.m.	908	48	24	202	911	1356	738	2094	
to Sept. 1981	1700 - 1750	(B)	"	338	21	12	71	175	510	273	783
	1750 - 1800	(C)	"	127	13	6	26	158	225	120	345
	1800 - 1850	(D)	"	72	2	4	20	70	115	60	175
	1850 - 1900	(E)	"	78	2	1	13	62	91	66	157
	1900 - 1950	(F)	"	51	0	1	3	50	76	46	122
	1950 - 2000	(G)	"	25	4	3	8	15	33	22	55

Table - 5 - Altitudinal Distribution of tsetse flies using V/P method from September 1980 to August 1981.

Months/Year	Altitude	Species	Teneral	Non - Teneral				M	F	Total
				Hunger category						
				I	II	III	IV			
September /	1650 - 1700	(A) G.m.	505	53	139	330	1399	1413	1019	2432
1980/	1700 - 1750	(B) "	174	25	40	144	508	511	376	887
September /	1750 - 1800	(C) "	82	13	26	77	240	268	194	462
1981/	1800 - 1850	(D) "	38	7	10	40	110	126	79	205
	1850 - 1900	(E) "	36	4	9	29	69	105	61	166
	1900 - 1950	(F) "	14	2	4	20	52	53	34	87

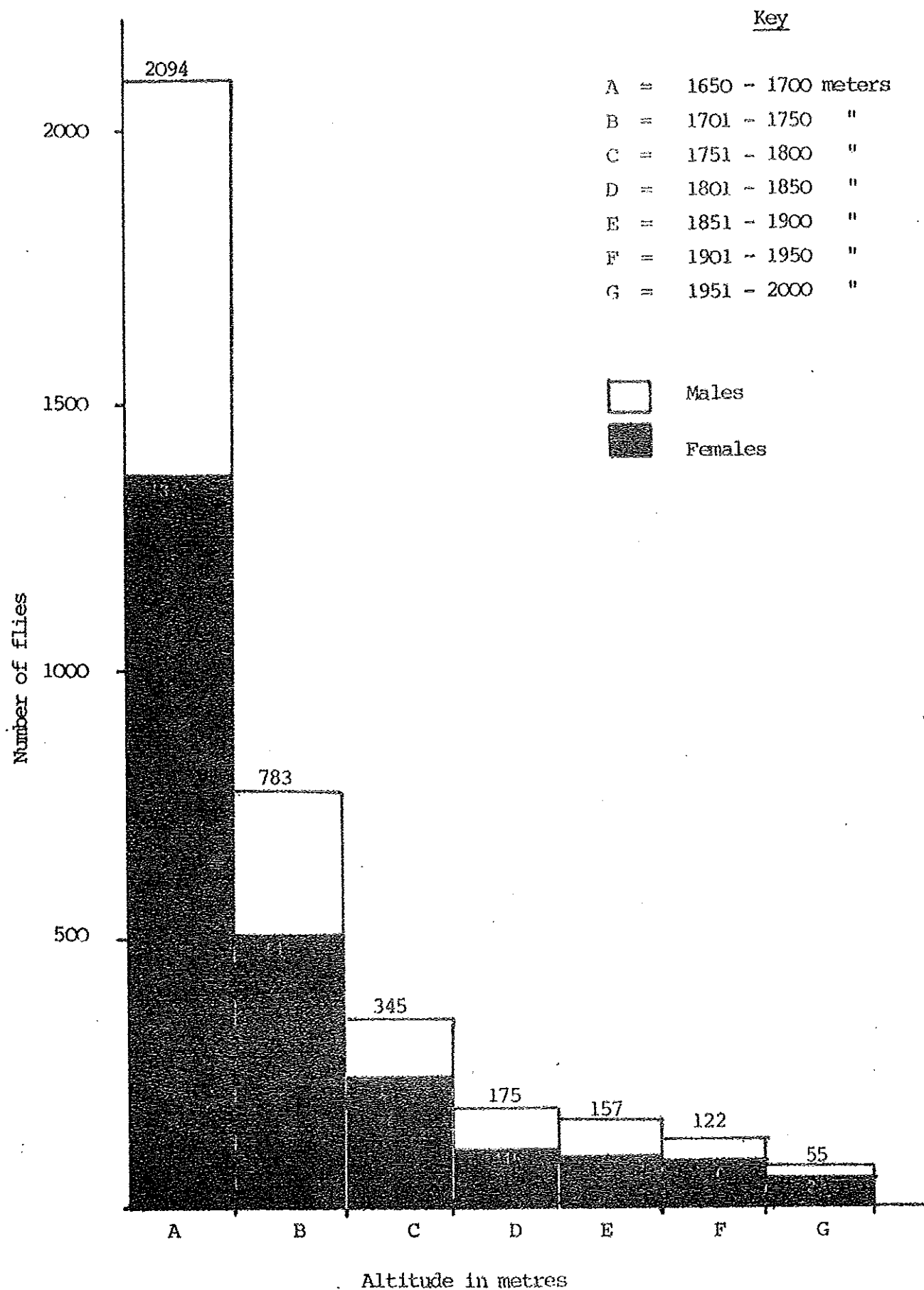


Figure 3 Number and sexes of tsetse flies collected at different altitudes during September 1980 to August 1981 using the Screen/Hand net method

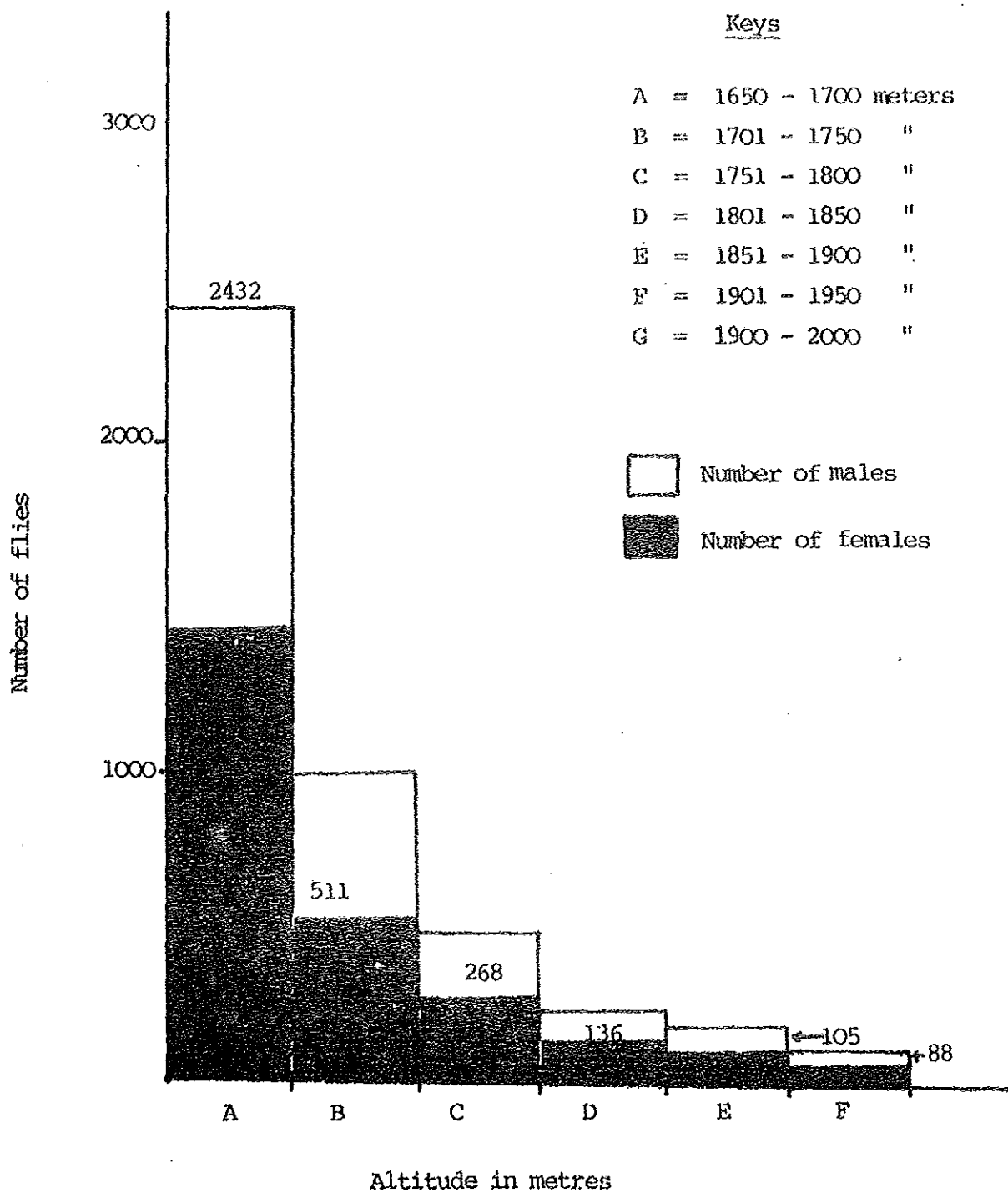


Figure 4 Numbers and sexes of tsetse flies collected at different altitudes during September 1980 to August 1981 using the Vehicle Patrol method.

5.3 Apparent Density

The apparent density of G. morsitans ugandensis as observed with Biconical traps indicates a significant rise in the months of April to August (Fig.5). Observations were not done for the months of September to December. On the other hand a year round collection with the Screen/Hand net and the Vehicle Patrol methods showed a rise in the apparent density from April to December (Figs 6 & 7 and Table 6). The apparent density dropped in January, February and March.

Table - 6

APPARENT DENSITY

Months (Year)	Temp. °C	RH%	Rainfall (mm)	Apparent Density		
				VP	S/H	BT
Sept 1980	29	60.1	4.5	145	169	-
Oct. "	29.5	34.09	2.64	153	150	-
Nov. "	29.83	33.90	0.1	100	125	-
Dec. "	30.77	41.51	0.0	140	130	-
Jan. 1981	32.32	39.16	0.17	70	69	15
Feb. "	36.03	35.78	0	37	45	18
March "	34.19	43.90	0.9	60	55	21
April "	35.71	41.83	1.88	120	140	71
May "	34.5	51.78	4.23	124	140	83
June "	32.96	57.78	4.75	150	160	72
July "	24.51	82.70	13.30	149	145	81
Aug. "	27.16	74.61	7.9	160	150	65

5.4 Seasonal Fluctuation

A year-round study of the tsetse population in the Finchaa area indicates that climatic factors, namely rainfall, relative humidity and temperature, have some bearing on the seasonal density of Glossina morsitans ugandensis as well as on the efficacy of the sampling methods (Fig. 8, Tables 7 and 8). In general it appears that there is only one peak in a year with numbers of tsetse flies increasing during and immediately after the rainy season. Observations carried out with the Biconical traps does not give a complete picture of seasonal density,

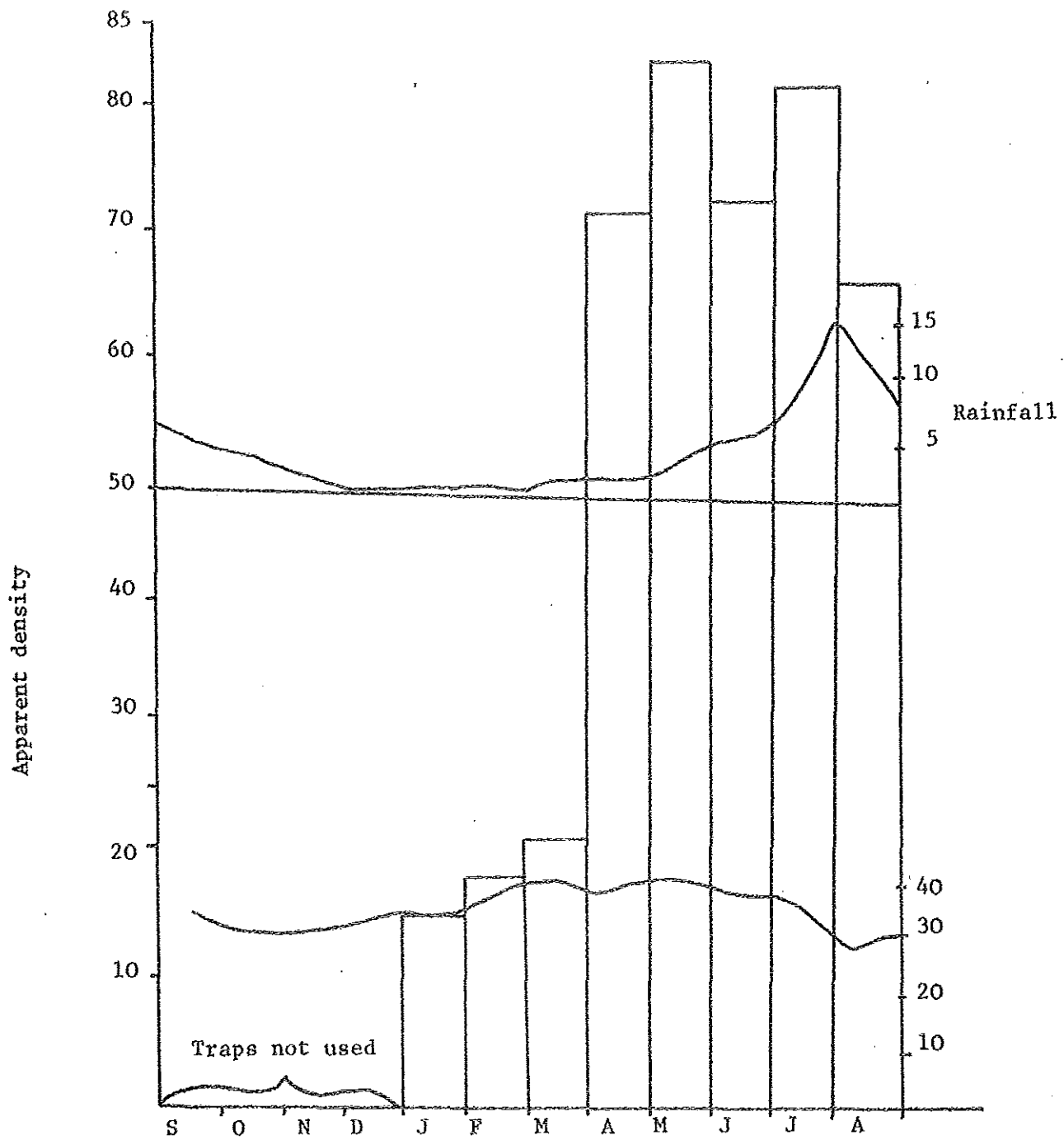


Figure 5 : Seasonal variation in apparent density of *Glossina morsitans ugandensis* using the Biconical traps during January to August 1981.

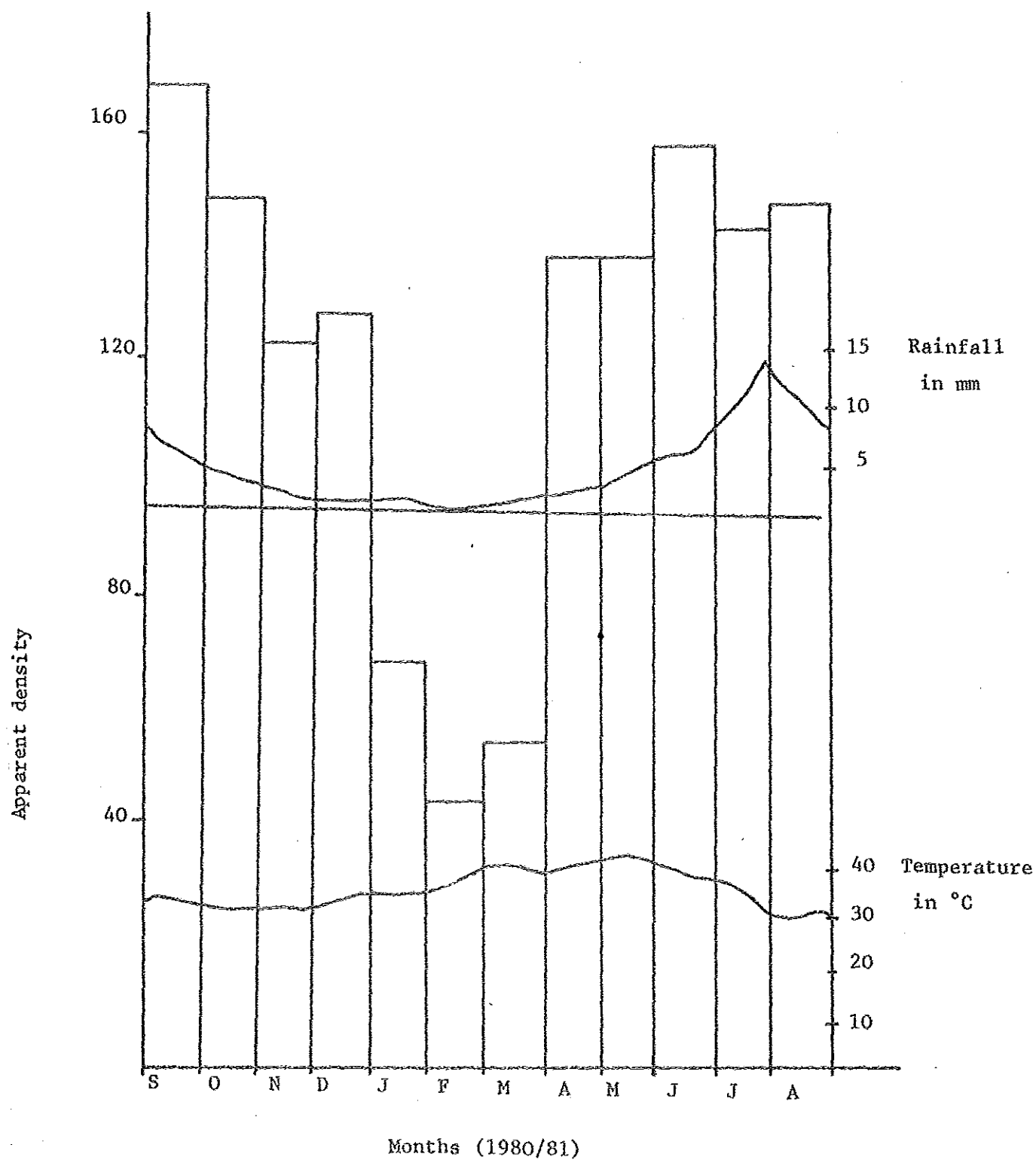


Figure 6 : Seasonal variation in apparent density of *Glossina morsitans ugandensis* using the screen/hand net method during September 1980 to August 1981.

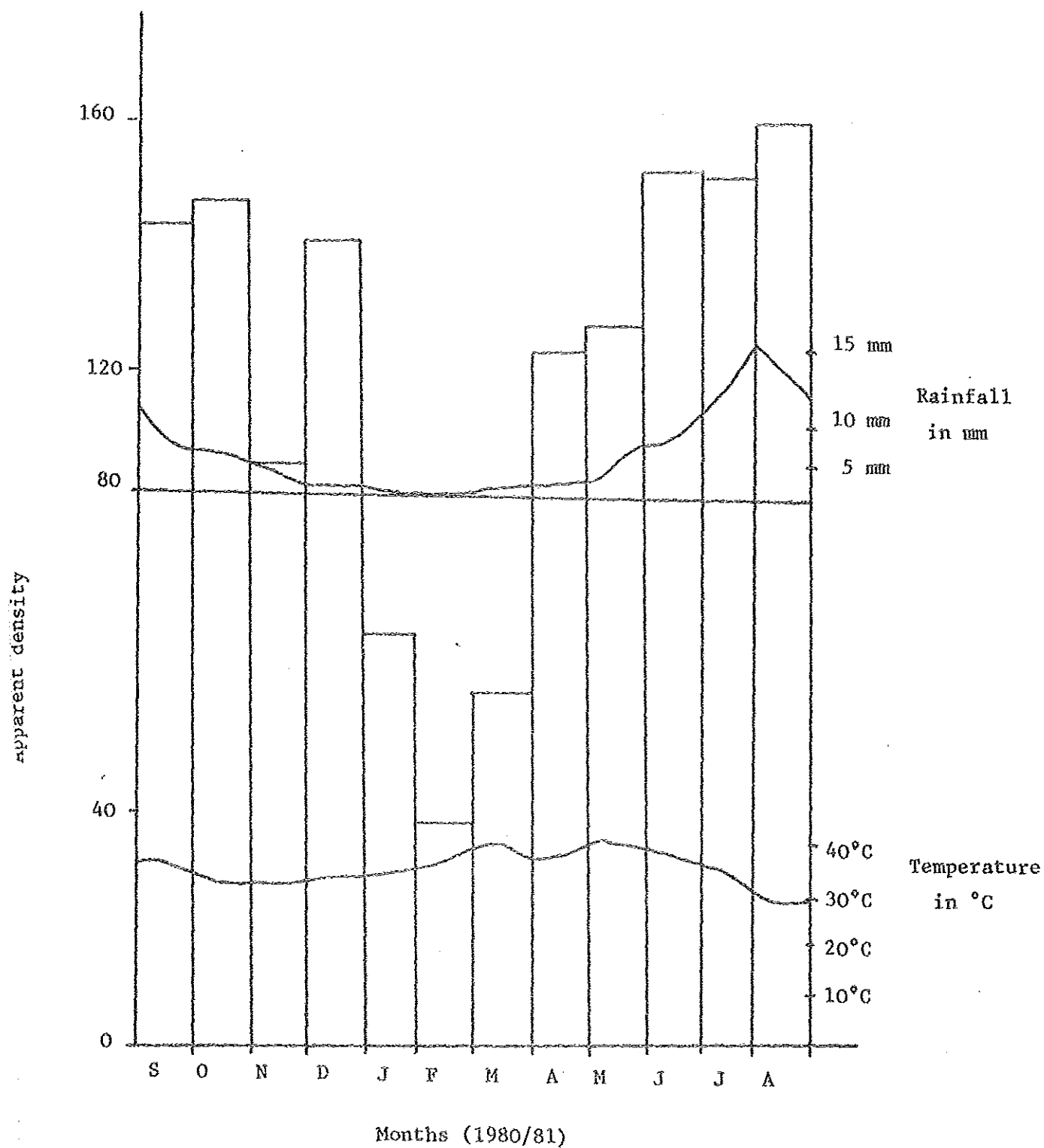


Figure 7 : Seasonal variation in apparent density of *Glossina morsitans ugandensis* using the vehicle patrol method during September 1980 August 1981.

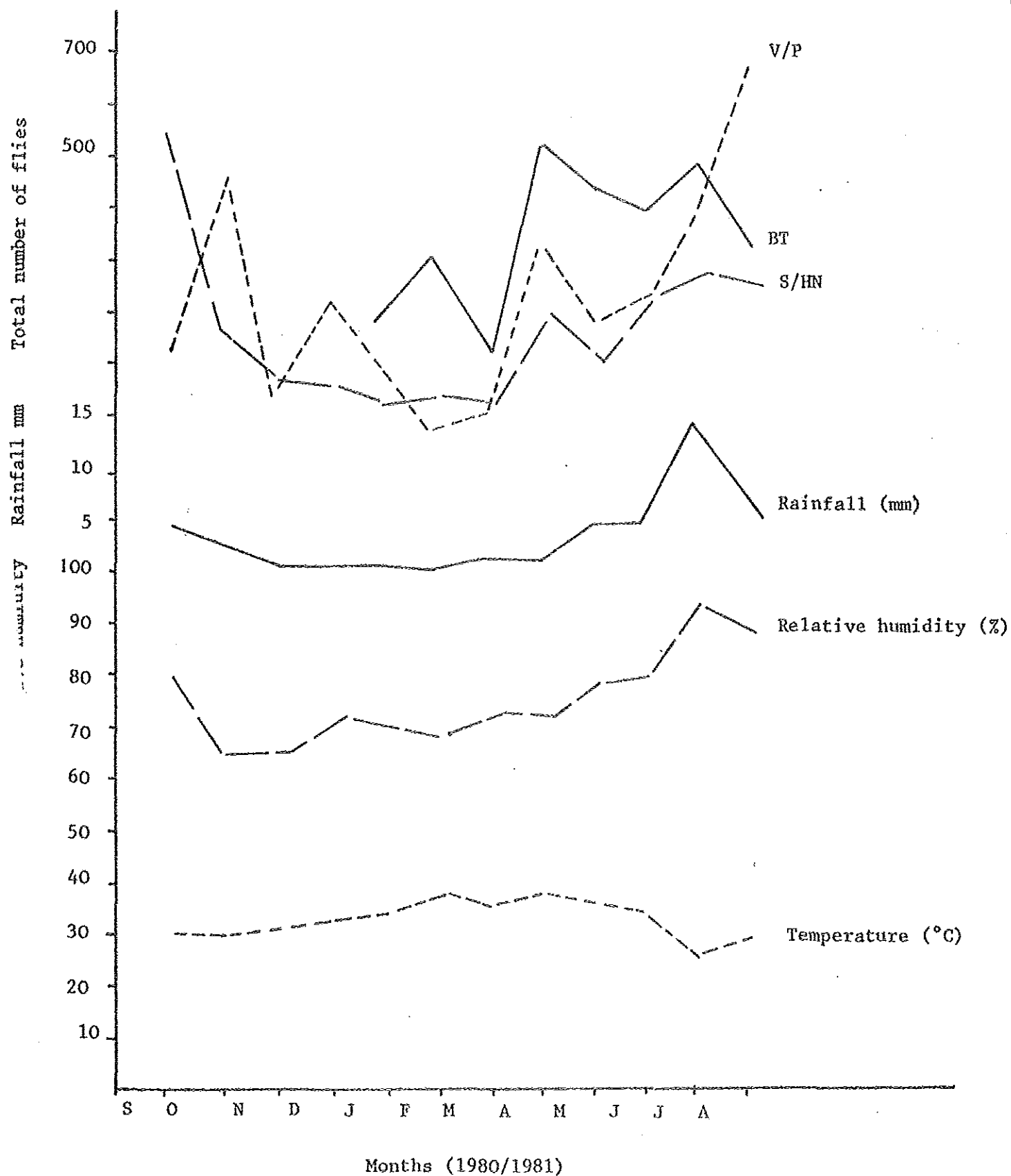


Figure 8 : Seasonal fluctuation of *Glossina morsitans ugandensis* in the Finchaa River Valley during September 1980 to August 1981 using the Biconical Traps (BT), Vehicle Patrol (VP) and Screen/Hand net (S/HN) methods.

but seasonal changes in flies caught were similar to those observed by the other 2 methods.

Since there is a marked population increase and decrease during the wet and dry seasons, respectively, one can conclude that the density independent mortality factor plays an important role in affecting the tsetse population in the valley.

Table 7 - Relationship between climatic factors and total fly catches using the Vehicle Patrol and the Screen/Hand net methods, and the Biconical traps.

Months/	Mean monthly Temperature (°C)	Mean monthly RH%	Mean monthly Rain fall (cm)	Fly catches and methods		
				VP	S/HN	BT
Sept/1980	29.00	60.1	45	234	636	-
Oct/1980	29.51	34.09	2.64	584	259	-
Nov/1980	29.83	33.90	0.1	106	164	-
Dec/1980	30.77	41.51	0.0	307	155	-
Jan/1981	32.32	39.16	0.17	167	121	281
Feb/1981	36.03	35.78	0.0	51	138	438
March/81	34.19	43.90	0.9	98	139	227
April/81	35.73	41.83	1.88	404	300	603
May/1981	34.5	51.76	4.23	262	222	530
June/81	32.96	57.76	4.75	326	335	491
July/1981	24.51	82.70	13.30	475	371	567
August/81	27.16	74.61	7.9	727	360	418
	$\bar{x} = 31.37$ SD = ± 3.54	$\bar{x} = 49.76$ SD = ± 16.09	$\bar{x} = 3.36$ SD = ± 3.39	$\bar{x} = 311.75$ SD = ± 206.13	$\bar{x} = 266.66$ SD = ± 147.99	

Table 8 - Correlation between mean monthly temperature (A), mean monthly relative humidity (B) and mean monthly rainfall (C) and fly capture using the three sampling methods.

A)		
Temperature versus Sampling methods	r	Significance at 1 d. f
T X S/H	0.51443	Significant
T X VP	0.64227	"
T X BT	0.12700	Not significant

B)		
RH % versus sampling methods	r	Significance at 1 d. f
RH X S/H	0.63379	Significant
RH X VP	0.54079	"
RH X BT	0.3600	Not significant

C)		
Rain fall versus sampling method	r	Significance at 1 d. f
RF X S/H	0.424409	Significant
RF X VP	0.62103	"
RF X BT	0.4823	"

5.5 Age Structure

The age structure of male and female Glossina morsitans ugandensis was determined by means of male wing-fray degrees (Jackson, 1946) and ovarian aging table 18-p.89 (Saunders, 1963; Challier, 1965), respectively. Plate 9 shows how the wing-fray values were treated in the present study.

Figures 9, 10 and 11 indicate the mean estimated ages of male Glossina morsitans ugandensis collected by the three different methods in different months.

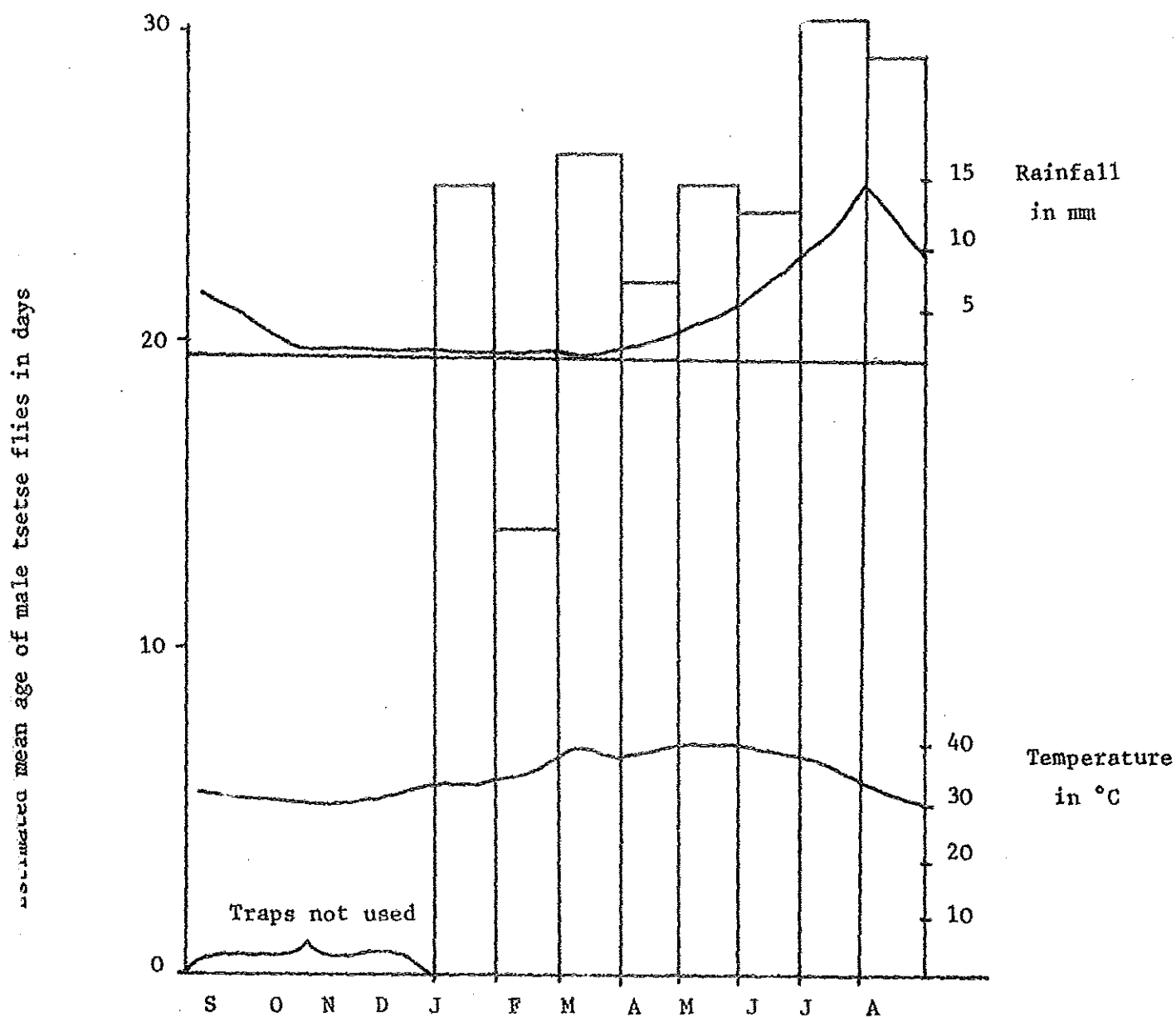


Figure 9 : Estimated mean age of male *Glossina morsitans ugandensis* collected by the Bioconical Traps during January to August, 1981.

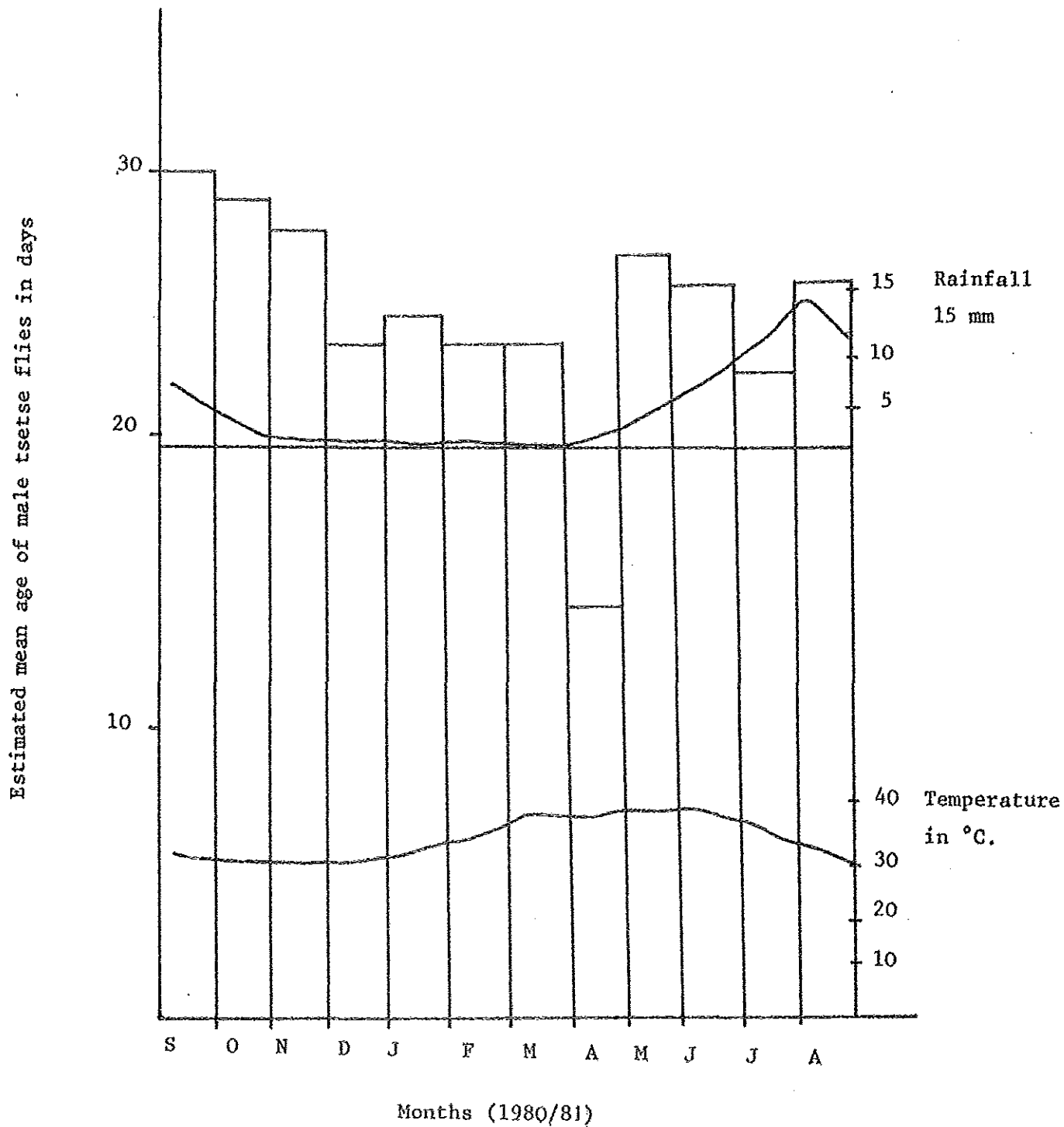


Figure 10 : Estimated mean age of male *Glossina morsitans ungodensis* collected by screen/hand net method during September 1980 to August 1981.

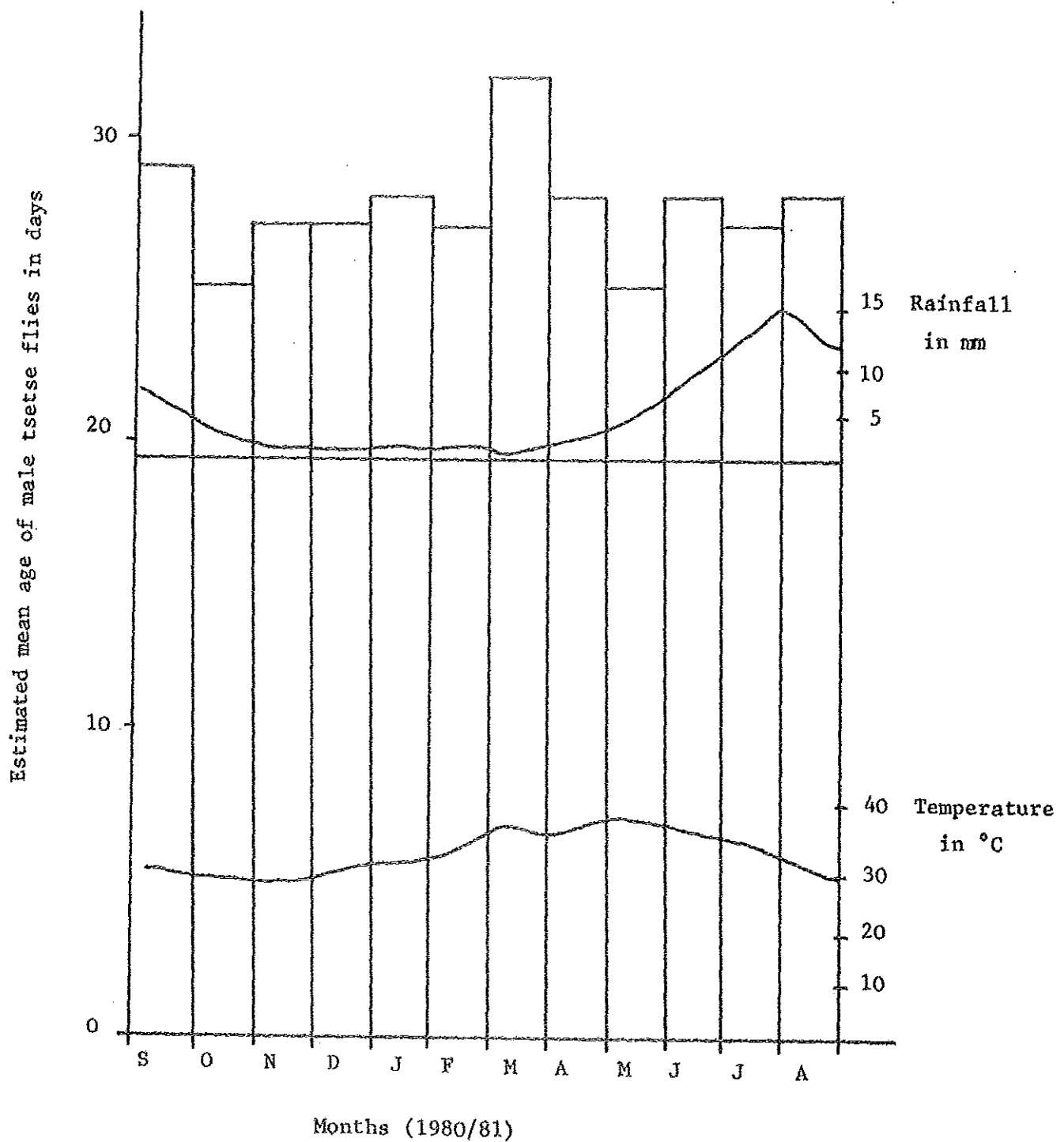
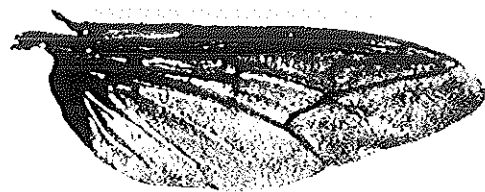
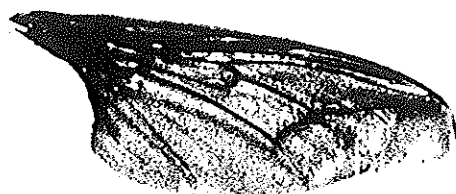


Figure 11 : Estimated mean age of male *Glossina morsitans ugandensis* collected by vehicle patrol method during September 1980 to August 1981.

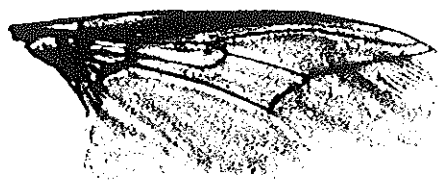


Approximate age
Category

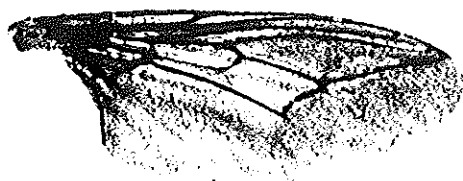
Category 1



Category 2



Category 3



Category 4



Category 5



Category 6

Plate 9 - Mounted wings of males of Glossina morsitans ugandensis showing wing frays and approximate age category of the flies

Table - 11 -

C. Vehicle Patrol (Sept. 1980 to August 1981)

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August
M												
W	29	25	27	27	28	27	32	28	25	28	27	28
F	days	days	days	days	days	days	days	days	days	days	days	days
V												

5.15 Diel Activity

The diel (diurnal) activity of Glossina morsitans ugandensis in the Finchaa River Valley shows two peaks (bimodal). The first peak occurs from 9:00 to 12:00 hours while the second occurs from 15:00 to 17:00 hours. The largest numbers were collected at 10:00 and 16:00 hours, when the relative humidities and the temperatures were around 97% and 30°C (range 27 to 32), respectively (Fig. 12).

5.16 Sex Distribution and Physiological Condition

The sex distribution for each month for periods September 1980 to August 1981 is indicated for Vehicle Patrol and Screen/Hand net methods and for January to August 1981 for the Biconical traps (Fig. 13 a, b and c and Table 12). In general, slightly more males than females are caught each month by the two former methods, but the Biconical traps caught more females than males during April to August 1981.

The difference in catches becomes obvious in the months of November to January, April to August or September and June to July for the Vehicle Patrol, the Screen/Handnet methods and the Biconical traps, respectively.

As far as the physiological condition is concerned, especially the hunger state, on the whole more non-teneral than teneral male and female tsetse flies were collected by the three sampling methods (Tables - 12 & 15). However, slightly more teneral than non-teneral male and female flies were collected in November, January and February with the Screen/Hand net method, while this is so only in December with the Vehicle Patrol method.

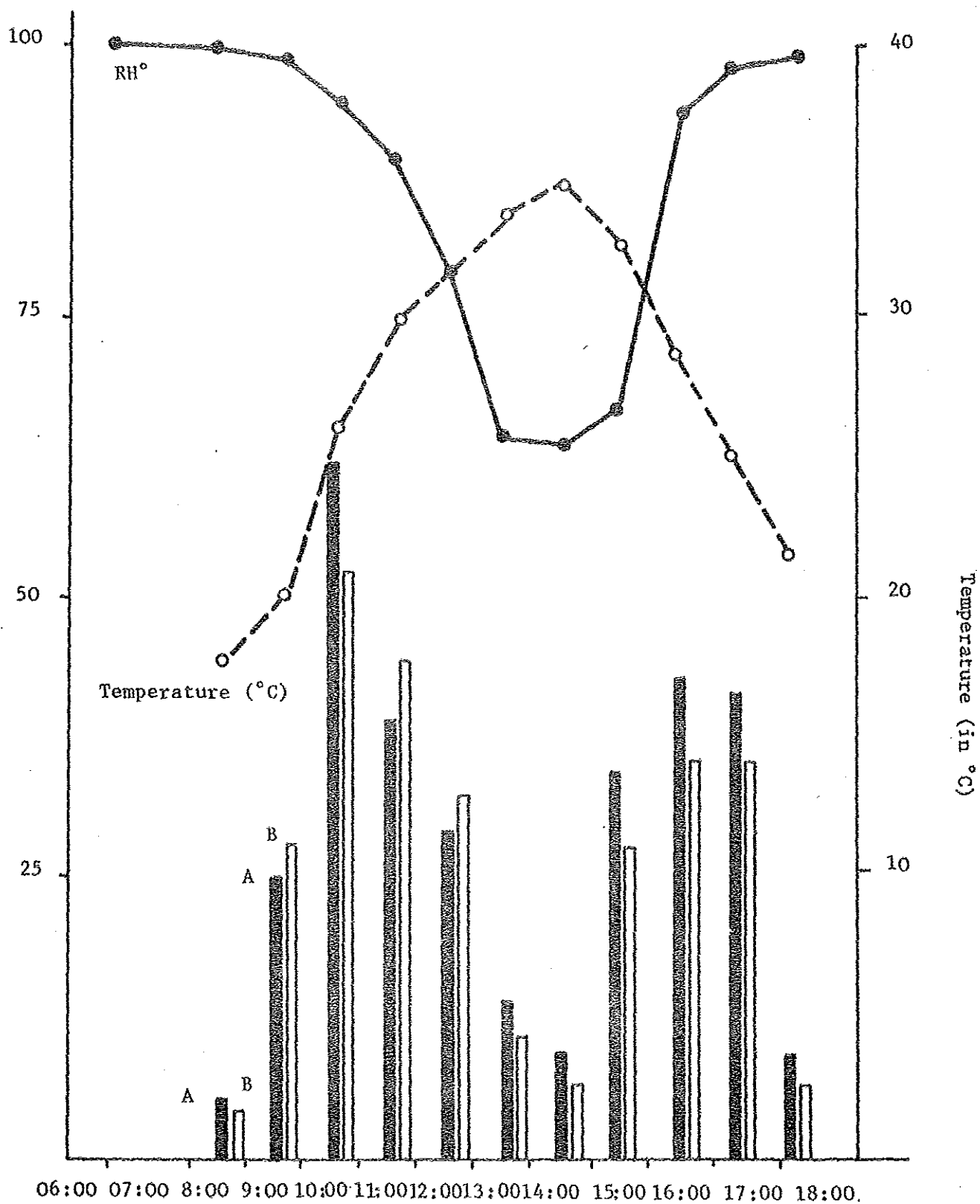


Figure 12 : Percentage of active flies collected by two different methods at different temperatures, relative humidities and hours of the day for three consecutive days.

- A - Screen/hand net method (black)
- B - Biconical traps (red)

Table 12 - Number of Teneral and Non-teneral Male and Female Glossina morsitans ugandensis Collected each month using the Biconical Traps, the Vehicle Patrol and Screen/Hand Net Methods.

53

Month / Year	Biconical Traps					Vehicle Patrol					Screen/Hand Net					
	T	NT	M	F	S	T	N	NT	M	F	S	T	NT	M	F	S
September, 1980	-	-	-	-	-	29	205	159	75	234	332	304	307	329	636	
October, "	-	-	-	-	-	78	500	320	258	578	127	132	165	94	259	
November, "	-	-	-	-	-	12	111	76	47	123	89	75	116	48	164	
December, "	-	-	-	-	-	120	25	105	40	145	68	87	115	40	155	
January, 1981	35	252	179	108	287	19	148	103	64	167	66	55	88	33	121	
February, "	47	390	266	171	437	4	52	28	28	56	81	57	83	55	138	
March, "	16	205	140	81	221	0	89	56	33	89	38	101	102	37	139	
April, "	68	526	280	314	594	90	312	256	146	402	36	264	214	86	350	
May, "	68	460	248	280	528	69	193	143	119	262	95	127	171	51	222	
June, "	45	446	169	322	491	29	301	202	128	330	151	185	238	97	335	
July, "	55	602	302	365	667	113	362	302	173	475	169	202	230	141	371	
August, "	28	389	167	250	418	180	547	399	328	727	151	209	231	129	360	
Total	362	3290	1805	1847	3652	743	2845	2149	1439	3588	1403	1797	2060	1140	3200	
Percentage	10	90	48	52	20.7	79.2	59.9	40.1		43.9	56.2	64.3		35.7		

Table - 13 - Distribution of sexes and physiological conditions in population of Glossina morsitans ugandensis captured by the Biconical traps during January to August, 1981.

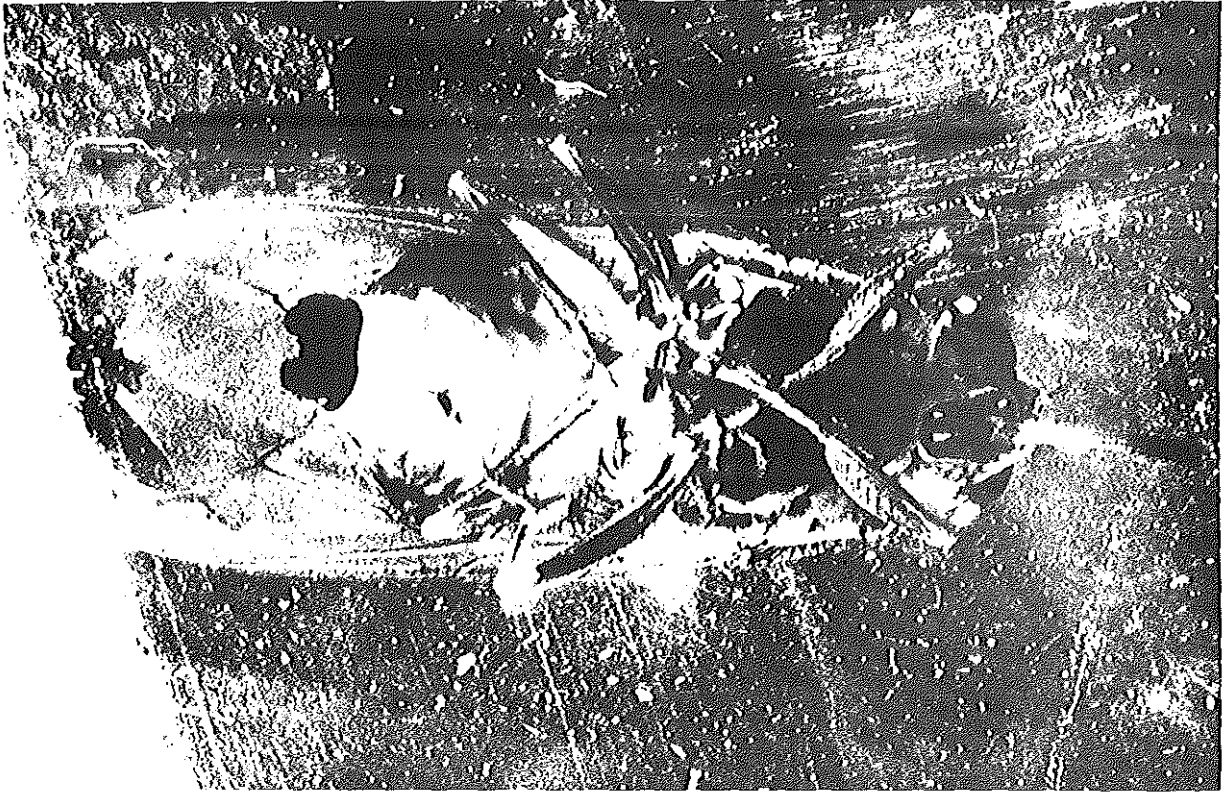
Months/Year	Teneral	Non - Teneral					M	F	T
		I	II	III	IV	Total			
January 1981	35	15	83	109	45	252	179	108	257
February "	47	19	148	159	64	390	266	171	437
March "	16	3	87	96	19	205	140	81	221
April "	68	17	221	224	64	526	280	314	594
May "	68	24	152	191	93	460	248	280	518
June "	45	20	152	199	75	446	169	322	491
July "	55	29	280	203	90	602	302	365	667
August "	28	15	128	164	82	389	167	250	418
Total	362	142	1251	1138	531	3290	1805	1842	3652
Percentage	10	5	36	33	16	90	48	52	

Table - 14 - Distribution of sexes and physiological conditions in populations of Glossina morsitans ugandensis captured by the Screen/Hand net method during September 1980 to August 1981.

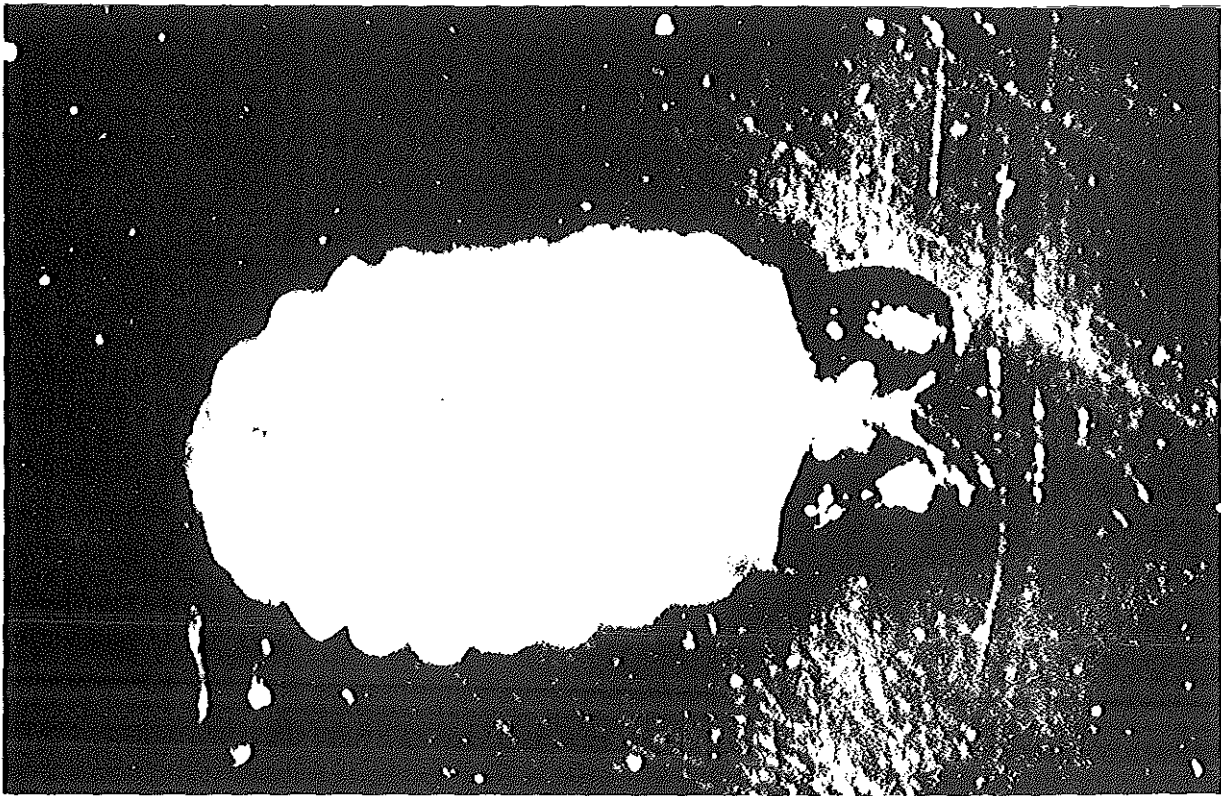
Months/Year	Teneral	Non - Teneral					M	F	T
		I	II	III	IV	Total			
September 1980	332	19	5	22	258	304	307	329	636
October "	127	10	7	3	112	132	165	94	259
November "	89	6	2	4	63	75	116	48	164
December "	68	1	3	21	62	87	115	40	155
January 1981	66	5	0	4	46	55	88	33	121
February ""	81	6	0	2	49	57	83	55	138
March "	38	15	4	13	69	101	62	37	139
April "	36	5	1	62	196	264	214	86	300
May "	95	10	1	12	104	127	171	51	222
June "	151	2	6	32	145	185	238	97	335
July "	169	1	5	43	153	202	230	141	371
August "	151	2	0	42	165	209	231	129	360
Total	1403	82	34	259	1422	2055	2060	1140	3200
Percentage	43.8	2	1	8	44.4	55.2	64.3	35.7	

Table - 15 - Distribution of sexes and physiological conditions in populations of Glossina morsitans ugandensis captured by the Vehicle Patrol method during September 1980 to August 1981.

Months/Year	Teneral	Non Teneral				Total	M	F	T
		I	II	III	IV				
September 1980	29	26	1	38	140	205	159	75	234
October "	78	12	34	93	361	500	320	258	578
November "	12	6	2	20	83	111	76	47	123
December "	120	1	7	8	9	25	105	40	145
January 1981	19	5	8	31	104	148	103	64	167
February "	4	2	1	6	43	52	28	28	56
March "	0	1	6	53	29	89	56	33	89
April "	90	15	31	77	189	312	256	146	402
May "	69	6	14	62	111	193	143	119	262
June "	29	4	37	55	205	301	202	128	330
July "	113	9	33	49	271	362	302	173	475
August "	180	13	31	82	421	547	399	328	727
Total	743	100	205	574	1966	2845	2149	1439	3588
Percentage	20.7	2.78	5.71	16	54.8	79.3	59.9	40.1	



(A)



(B)

Plate 8 - Larva of G.M. ugandensis during larviposition by the female
(A) and after it has been deposited (B)

Number of tsetse flies collected using screen/handnet method.

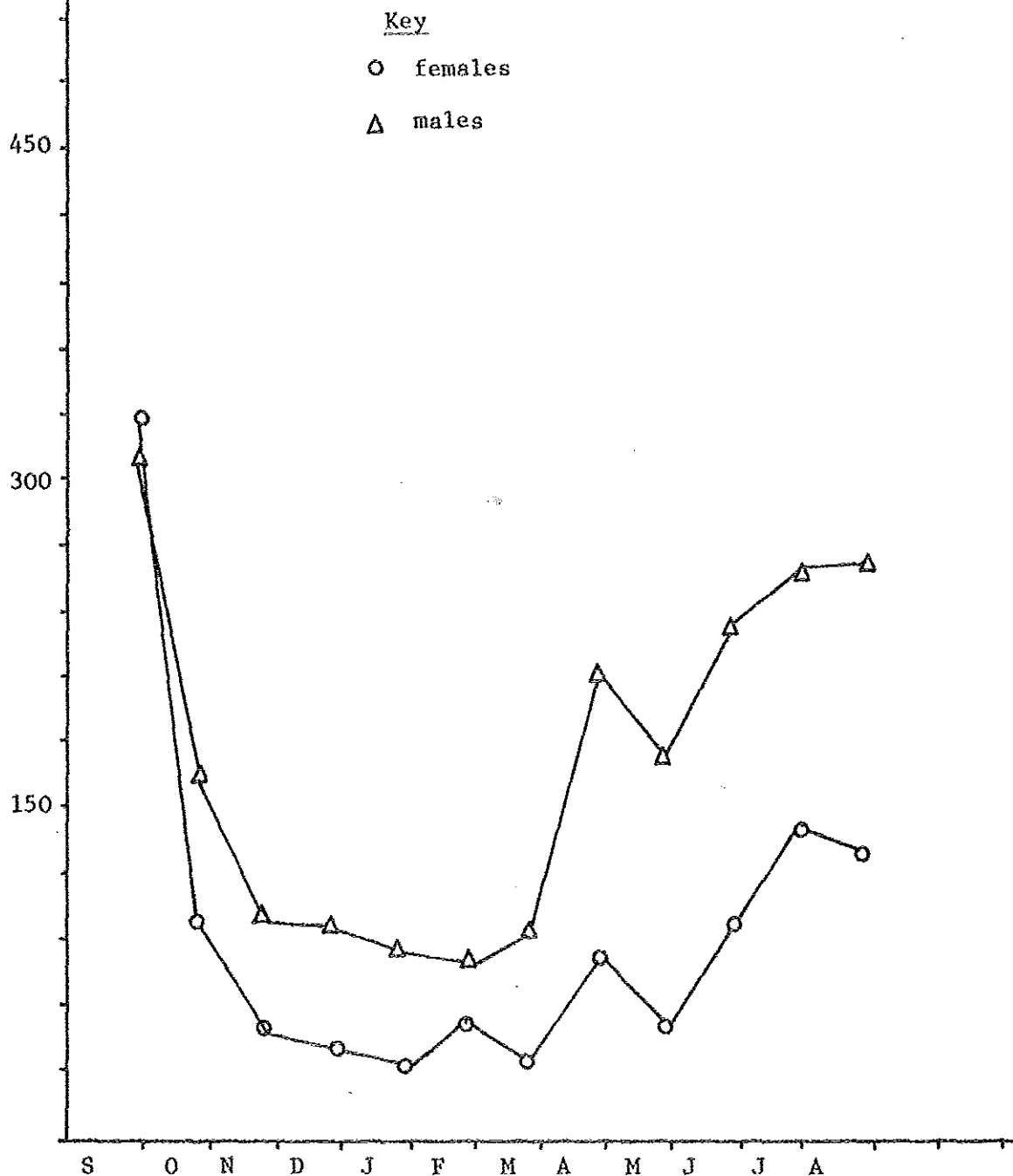


Figure 12 a : Sex distribution of population of *Glossina morsitans ugandensis* at each month using the screen/handnet method.

Number of tsetse flies collected using Vehicle patrol method.

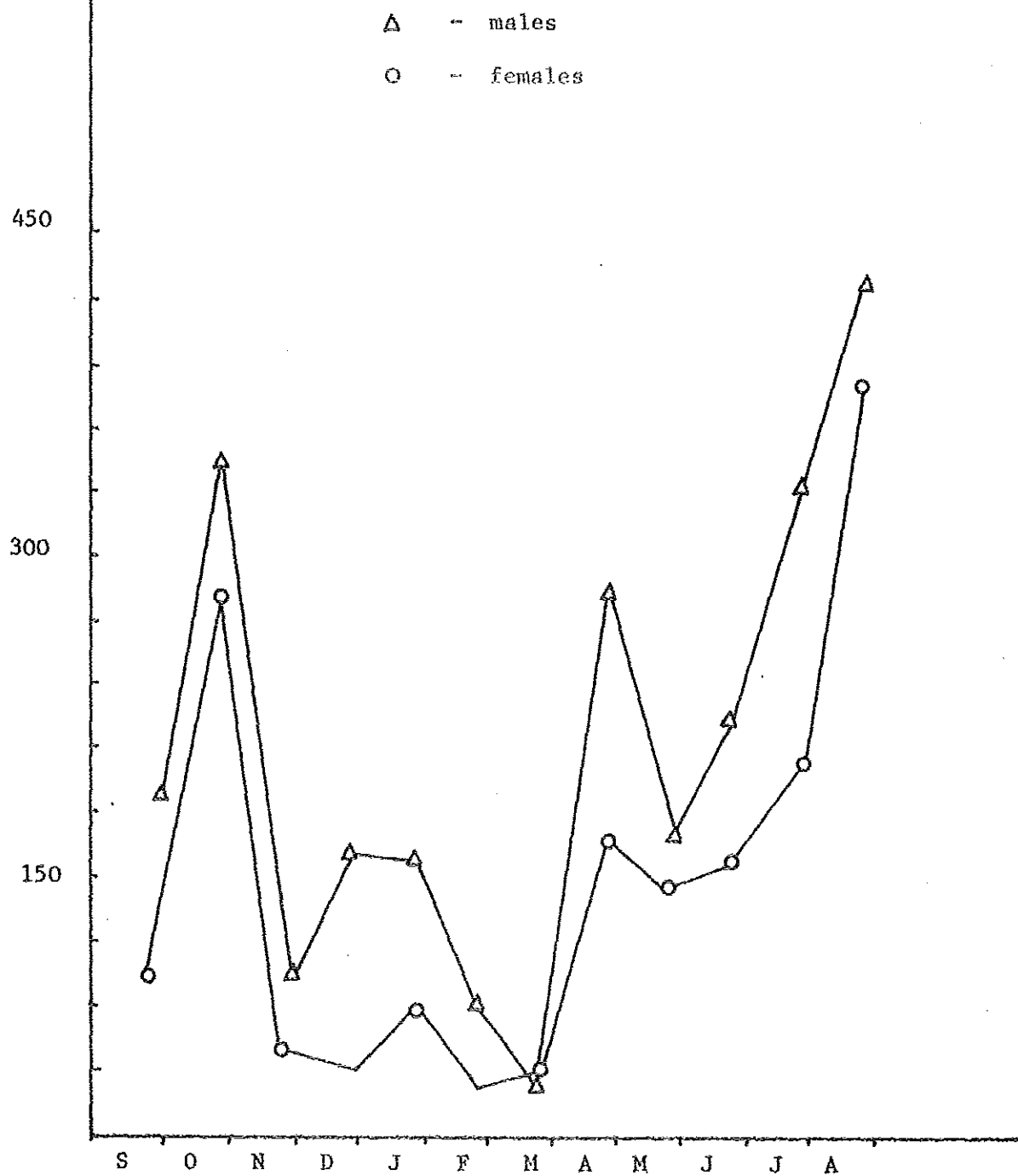


Figure 12 b : Sex distribution of populations of *glossina morsitans ugandensis* at each month using the vehicle patrol method.

Number of tsetse flies collected using Biconical Traps.

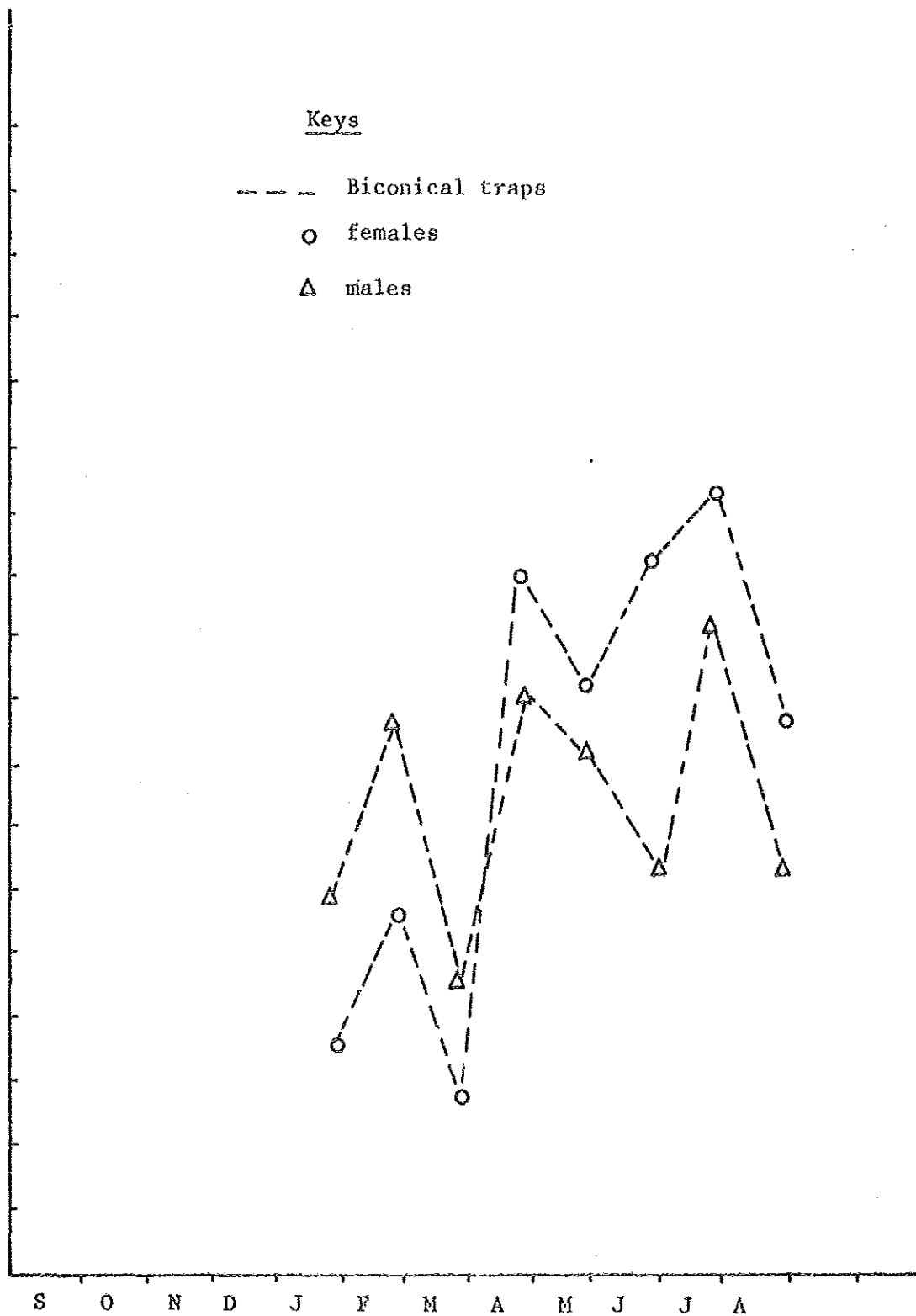


Figure 12 C : Distribution of population of *Glossina morsitans ugandensis* at each month using the Biconical traps.

5.17 Infection Rate

Infection of tsetse flies and cattle with Trypanosoma spp. was determined in the Finchaa River Valley by individual dissection of 640 Glossina morsitans ugandensis and thick and thin blood - smear examination of 22 cattle. Of the 640 flies examined 3 (0.5%) were found infected with Trypanoma vivax. On the hand, of the 22 cattle examined 8 (33%) had a double infection with Trypanosoma vivax and Trypanosoma congolense.

5.18 Natural and Adventitious Hosts of Glossina morstans ugandensis

Blood-meal analysis carried out at "the blood-meal identification unit, Imperial College, Silwood Park, England," on a total of 83 blood-fed Glossina morsitans ugandensis collected by the biconical traps and Screen/Hand net methods 74 were that of man, 5 of wild pig and man, 3 of Warthog and 1 of wild pig (Table - 16).

Table 16. Natural and adventitious hosts of Glossina morstans ugandensis in the Finchaa River Valley during September 1980 to August 1981.

Hosts	Number of fed G.M. Ugandensis	Sex		Percentage
		M	F	
Man	74	44	30	89
Wild pig and Man	5	-	5	6.0
Wars-hog	3	1	2	4.00
Wild pig	1	-	-	1.0

6 - Discussion

6.1 Species Composition

Working on the tsetse flies of the Wellega Administrative Region Langridge (1976) observed the existence of three different species, namely, Glossina morsitans ugandensis, Glossina tachinoides and Glossina fuscipes. The Abai (Blue Nile) River system, which has a direct contact with the Finchaa River Valley, is also known to harbour both G.m. ugandensis and G. tachinoides.

The study area had not been thoroughly surveyed before and hence no precise information on the species composition and degree of infestation was available at the beginning of the present work.

In spite of the close contact between the Abai (Blue Nile) River system and the Finchaa River Valley, and also the presence of similar habitats in both areas, Glossina morsitans ugandensis and Glossina tachinoides are found in the former area (Langridge, 1976; Ford & Katondo, 1973), while the present finding records only Glossina morsitans ugandensis in the latter area. This may indicate that the distribution of G. tachinoides away from their permanent homes (habitats) is very limited as compared to G. m. ugandensis. Langridge (1976) stated that G. m. ugandensis usually spread from the Abai River system across the river valleys to the escarpment leading to the highlands. The second reason for the absence of G. tachinoides in the present study might be a result of the slightly higher altitudinal level of Finchaa. In general, G. tachinoides have lower height limits than G. m. ugandensis although in some circumstances both have been caught at very high altitudes (Langridge, 1976).

The third reason is based upon interviews made with some of the old native farmers who knew about the existence of these flies in the Abai River system long before they heard of them in the Finchaa River Valley. If G. m. ugandensis has recently invaded the Finchaa Valley it may imply that this species may readily invade new territory faster than G. tachinoides.

6.2 Altitudinal Distribution

In the present study in the Finchaa River Valley Glossina morsitans ugandensis was collected at altitudes ranging from 1650 to 2000 meters (Fig. 3).

Various intervals flies have been collected from the edges of the escarpment at an altitude of about 2200m. This information has not been included in the year round collection made with the three sampling methods. To my knowledge this will be the highest height limit ever recorded for G. m. ugandensis both in Ethiopia and elsewhere in Africa. According to Langridge (1976) the height limits for G. m. ugandensis in Ethiopia is 1,650 m. while they may go up to 1700 m other parts of Africa (Buxton, 1955). However, the former author has recorded from Ethiopia (Gojjam) both Glossina morsitans ugandensis and Glossina tachinoides at nearly 1800 m. This was an exceptional circumstance which resulted from a grass-fire which forced the flies to move to a such height.

The unusual height of 2000 m and above observed for tsetse in the Finchaa Valley may be a result of:

- a) The sudden drop of the slope of the gorge reduced the difference in: temperature gradient, relative humidity percent, vegetation and soil. These factors play a role in setting a limit in the distribution of the flies.
- b) The similarity in the mean annual temperature, which is 27 - 29°C near the edge of the escarpment and 29-31°C at the bottom of the gorge. Although there is a significant altitudinal difference between the two places, i.e. 1600 m. at the bottom of the valley and 2010 m. at the edge of the escarpment, the temperature range at the edge of the escarpment is still quite favourable for the breeding, feeding and resting of the flies (Mulligan, 1970; Buxton, 1955).
- c) The presence of a large number of game animals from the bottom of the valley to the edge of the escarpment. The vegetation cover also extends up to the edge of the escarpment.

Buxton (1955) pointed out the strong relationship that existed between vegetation and tsetse food sources.

- d) Bush fires, which has been seen to drive out the flies from the bottom of the valley to the edge of the escarpment at 2010 m.

As shown in Figures (2 and 3) the fly capture increases at lower altitudes. This indicates that the lower altitudes in Finchaa are the permanent homes.

The frequency of teneral flies is also very high in lower altitudes (Table 3, 4, 5, 15 - 37). This shows that the lower altitudes are the best breeding grounds for the flies. Apart from this the temperature is slightly higher in the bottom of the valley and the vegetation cover is predominantly savanna woodland. Apparently, this ground makes the area suitable for the flies to breed, feed and rest (Buxton, 1955; Ford, 1971; Glasgow, 1963; FAO, 1979).

6.3 Apparent Density

The Apparent Density (A.D.) serves as an index for the seasonal fluctuation of the tsetse population in the valley. The A.D.'s obtained by the Vehicle Patrol and the Screen/Hand net methods show some degree of similarity, although this is not so with the Biconical Traps (Figs. 4, 5 & 6). The highest A.D. (169) was observed with the Screen/Hand net method in September 1980, which was around the end of the rainy season. The lowest A.D. (37) was observed with the Vehicle Patrol method in February 1981, at the end of the dry season. The present findings correspond very closely with previous works of Buxton (1955), Ford (1971) and Langridge (1976), and Putt et al. (1980).

Comparison of the A.D. of tsetse in the Finchaa River Valley with that observed for *Glossina morsitans ugandensis* in the Didessa River Valley by Langridge (1976), suggests that the degree of infestation in these two areas is of the same magnitude.

It would be interesting to mention at this juncture that there are some investigators who support the view that the population is constant and that changes in the apparent density of tsetse population might be a result of changes in the factors influencing the catching of these flies (Mulligan, 1970).

6.4 Seasonal Fluctuation

A. Sampling Methods and Climatic Factors

Fly catches at different seasons using different sampling methods were compared. The Vehicle Patrol method collected the highest numbers in October and August (warm and wet season) and the lowest in February and March (hot and dry season). The Screen/Hand net method collected the highest number in September and the lowest in January to March (Fig. 7). Collection with the Biconical traps is

Limited to the months of January to August. Even then, the pattern is more or less similar to catches with the other two methods, except for that in August.

The data therefore suggest that either of the three methods may be used to estimate the fly density of a segment of the population inhabiting the study area. However, of the three sampling methods the Vehicle Patrol method gave the highest fly capture. This observation agrees with that of Challier and Laviessiere (1973) and Turner (1980) for Glossina morsitans submorsitans in Mozambique.

The effect of climatic factors on fly capture is important and will be discussed below in the following order. They are:-

- i) Temperature versus fly capture
- ii) Relative humidity versus fly capture and
- iii) Rainfall versus fly capture

i) Temperature Versus Fly Capture

Flies captured by the Vehicle Patrol, the Screen/Hand net methods and the Biconical traps, showed strong, mild and weak negative correlations respectively, - 0.64227, -0.51443 and - 0.12700 with the mean monthly temperature (Table 5A). This means that with increase in temperature the fly population declines. This observation agrees with what has been said in Mulligan (1970), Jaemson (1978), and Turner (1980).

The weak negative correlation with the Biconical traps might be partly due to the stationing of some of these traps very close to forests and forest fringes where the climatic conditions are most favourable for the flies. It is therefore probable that some of the Glossina morsitans ugandensis would be attracted to the traps around the forest from the open grassland round about, when the hot, dry season was at its height (Nash, 1942).

ii. Relative Humidity Versus Fly Capture

Positive correlation was obtained between flies caught by the three different methods of collection and mean monthly relative humidity (Table 5B). This conforms with earlier findings by other investigators (Buxton, 1955; Ford, 1971; Turner, pers. comm.). Thus, increase in relative humidity will account for the positive growth in the apparent density of the Glossina morsitans ugandensis population.

The lowest positive correlation value (r) of 0.3600 was obtained for the traps. High r values of 0.63379 and 0.54079 were obtained for Screen/Hand net and Vehicle Patrol methods, respectively. This may be due to sampling bias. The Vehicle Patrol and Screen/Hand net methods seem to attract flies in search of food and/or mates while traps primarily capture flies in search of shae (Jaennson, 1978).

iii) Percipitation Versus Fly Capture

Here again a positive correlation was obtained between flies caught by the three sampling methods and the mean monthly precipitation (Rainfall) (Table 5c).

Rainfall is known to affect puparial development directly and the eco-distribution of the fly and the mammalian hosts indirectly. The indirect effect is associated with the impact of precipitation on vegetation (Buxton, 1955; Mulligan, 1970; Ford, 1971; FAO, 1982). The highest positive correlation is shown between percipitation and Vehicle Patrol. This could be due to the attractiveness of the sampling method to the fly (Muirhead - Thomson, 1968).

6.5 B. Seasonal Changes in the Population

a) The Wet Season (June - October)

The highest catch-levels were obtained during and immediately before and after the rainy season (Table 4 and Table 6)

In September and October, 1980, at the end of the rainy season the monthly mean temperature was 29°C , the monthly mean relative humidities were 60 and 30 percent. The monthly mean precipitation were 4.5 and 2.64 mm, respectively. The abundance of tsetse flies in this season could be due to a favourable climatic condition (Mulligan, 1970). In a productive biosystem if there is high rainfall and high temperature the area is likely to regain its vegetation cover thus making good grazing for the mammalian hosts of tsetse flies. Moreover, the vegetation at this time is in full leaf making the areas surrounding favourable and would indirectly exert an influence on the density and eco-distribution of the flies in a given area (Jaennson, 1978).

b) Cool Dry Season (November and December)

During this season the mean monthly temperature was 30°C, mean relative humidity 30 and 40 %, and mean monthly rainfall of 0.1 mm and zero, respectively brought a decline in the level of flies caught, especially with the Screen/Hand net method. The frequency of fly capture in November and December was low, presumably due to a low emergence rate resulting from the relatively cool conditions. The sharp decline in the rainfall and relative humidity at this time might have created a moisture-gradient which probably affected the moisture content and temperature of the soil. This could have affected the incubation period of the puparia (Mulligan, 1970, Lambrecht, 1980).

Since the vegetation cover did not show any noticeable change at this time the decline in the fly-population could not be directly associated with it.

c) The Hot Dry Season (January - March)

The hot dry season is characterized by a mean monthly temperature of about 35°C, with a mean monthly relative humidity of 35% and 40% and a mean monthly precipitation approaching 0.5 mm. The lowest catches of Glossina morsitans ugandensis were obtained in this season. Apparently, the decline in the fly population could be a result of an accelerated fat consumption presumably a result of the high temperature and perhaps the absence of animal hosts. In addition the low moisture content of the soil at this time might adversely affect the steady development of the puparium (Glasgow, 1969). On the other hand the relative humidity observed in the study area at this time may not be that adverse as has been observed for Glossina morsitans ugandensis population (Buxton, 1955).

The decline in the density of tsetse flies of Finchaa in this season was associated with bush fires that prevailed from January to March, 1981. It is presumed that this would affect the puparia in the soil and drastically alter the habitats for resting adults.

One of the most important and noticeable factors that would change the ecology of the valley could be the bush fires.

The bush fires not only affected the density of flies but also their distribution within the valley. The population distribution of the flies before the fires was fairly uniform, with a steady increase as one descended from the edge of the escarpment to the bottom of the gorge. However, after the on set of the fire the fly population in general declined, and the flies concentrated close to the river and the streams and the surrounding vegetation. The flies were driven out from the grassland and the dry-woodland areas to find a new habitat near the escarpment at a height of some 2010 meters. Some of the mammalian hosts were also driven to thick riverine evergreen woodland and some - probably migrated in search of grazing and perhaps left the tsetse fly-belt. Consequently, the flies were denied their normal habitats and their normal food source (Langridge, 1976).

d) The Short Rainy Season (April and May)

In the middle of the short rainy season, a build-up of the fly population was observed. Except for a very slight deviation we observe a typical pattern in Fig. 7 (Buxton, 1955; Ford, 1971; Jaemson, 1978; Turner, per. comm.).

6.6 AGE STRUCTURE

According to Buxton (1955), Jackson (1946), Mulligan (1970) and FAO (1982) the wing frays of young males are intact (plate 9) during the first 1 to 7 days after emergence and that teneral males and females have not had their first blood-meal at about 2 days after emergence.

Three sampling methods were employed to evaluate the age composition. All showed similar results in that most of the flies caught were non-teneral. Some of the flies caught were in the reproductive and post-reproductive stages. The above conditions entail that,

- a) The flies were in epidemiologically dangerous stages meaning that the risk of infection in the flies at these stages was high. To reach the infective stage the salivarian trypanosomes need 27 days in the case of T. Brucei, 12 days in the case of T. congolense and 5 days in the case of T. vivax (Lambrecht, 1980).
- b) If ecological conditions remained undisturbed the tsetse population would increase at these stages (Odiambo, 1966; Rogers, 1972; Nash, 1968; Jordan, 1957). The results obtained by Turner (1980) for Glossina morsitans submorsitans in Mozambique agrees fairly well with the age structure of Glossina morsitans ugandensis in the Finchaa River Valley.

Table 17 - Numbers and percentage of teneral and non-teneral female Glossina morsitans ugandensis collected by the Biconical traps from January to August 1981 and dissected for ovarian examination.

Total number of flies dissected	Teneral Females	per-centage	Non-Teneral	per-centage	Non-Teneral pregnant	per-centage
600	180	30	360	60	60	10

Table 18 - Numbers and estimated ages of female Glossina morsitans ugandensis collected by the biconical traps from January to August 1981 and dissected for ovarian examination (saunders, 1962)

	Number in sample	Approximate age in days			
		0	1	2	3
		1 - 8	8 - 16	20 - 30	30 - 40
January, 1981	75	20	45	8	2
February, 1981	75	24	40	9	3
March, 1981	75	18	50	6	2
April, 1981	75	26	39	6	1
May, 1981	75	16	46	10	2
June, 1981	75	24	46	5	3
July, 1981	75	19	27	9	4
August, 1981	75	33	67	7	1

0 - No ovulation or only one -
No larvae
(1-8) days

1 - Two ovulations = one larvae
(8-16) days

2 - Three Ovulation = two
Larvae (20-30 days).

The ovarian ageing of this species of flies showed quite similar results to wing fray method. Most of the flies, including the pregnant ones, were non-teneral (70%). Some of the pregnant flies were observed larvipositing in the traps and at other times pupae have been collected from within the traps (plate 8). The remaining 30% examined were teneral flies. The above observation is in agreement with that of Buxton (1955), Challier et al. (1977), Challier et al. (1980) and FAO (1982) for a typical age structure of populations of other tsetse flies.

6.7 Diel Activity

The pattern of the diel (diurnal) activity of Glossina morsitans ugandensis exhibited a biphasic-shape with a high morning peak (09:00 - 12:00 local time), a midday depression (12:30 - 14:30), and a late afternoon peak (15:00 - 17:00) which was some what lower than the morning peak (Fig. 12). The number of female flies collected early in the morning were quite high. Later in the morning the frequency of teneral and non-teneral male flies increased. But on the whole the female capture for the day with both the Screen/Hand net method and the Biconical traps was higher than the male. This finding agrees with the results obtained by Muirhead - Thomson (1968) and Turner (1980) for G. morsitans morsitans in Mozambique.

The biphasic activity pattern of G. m. ugandensis captured by both methods conforms to the V - shape pattern of the spontaneous flight activity of G. morsitans West in the laboratory (Jaennson, 1978). This pattern also confirms with the diel activity of G. morsitans.

Light intensity and temperatures are considered to affect activity of tsetse flies. Most tsetse stop being active as darkness approaches (Jaennson, 1978). On the other hand, high temperatures of about 30°C and above seem to have a pronounced effect in reducing the midday activity of Glossina morsitans ugandensis, as has been observed for other tsetse by Jaennson (1978) and Turner (1980), among others.

The relative humidity curve is positively correlated with fly activity and negatively correlated with temperature.

Data on relative humidity and temperatures have been used as an indirect measure of the diel activity of G. m. sulmorsitans (Glasgow, 1963).

6.7 - Sex Distribution and Physiological Condition

In the present study more males than females were caught by the Screen/Hand net (64%) and the Vehicle Patrol (59.8%) methods. This indicates the consistency in the manner by which each capture method is selective in catching members of the both sexes. However, the Biconical traps captured more males than females in the months of January to May while the reverse of this pattern is observed for the months of April to August when more females than males were captured. These findings are fairly typical in that the Screen/Hand net and the Vehicle Patrol methods usually capture the sexually appetitive and hungry male flies, where as the biconical traps normally capture mostly female flies that come to rest (Jaennsen, 1978; Turner, 1980; Challier and Turner, Per. comm.).

With regards to the hunger state of the catch, Screen/Hand net and Vehicle Patrolled fly rounds exhibited a high proportion of flies in the advanced hunger state - category IV.

Fly catches by the Biconical traps exhibited a high proportion of flies in the intermediate hunger states - categories II and III. Such a high catch of the replete and intermediate stages would be a result of a continued activity mostly by the hungry and gravid females in search of a blood meal as well as darkened, humid places for resting and larviposition.

The present findings with the Biconical traps agree with the results obtained by Turner (1980) and Challier (1980) with Langridge and Biconical traps. Both caught substantially more females than males. 74% and 83% females were caught with the Langridge and Biconical traps, respectively. Large proportions of the catches were in the intermediate hunger state.

The difference between the trap catches and Screen and Vehicle fly-round catches could be associated with the behaviour of the flies and the attractiveness of the sampling methods (Muirhead - Thomson, 1968; Buxton, 1955; FAO, 1982).

6.9 - Natural and Adventitious Hosts

The survival and success of morsitans group flies on the whole is known to be dependent on the presence of wild bovids and suids (Mulligan, 1970). It has been also stated that unless G. morsitans could alter its feeding pattern and become adapted to a diet of man and domestic animals, as have the riverine tsetse (Palpalis Group), it may well lose its empire in the ensuing centuries.

The present investigation showed that Glossina morsitans ugandensis had 89.1 percent of their blood-meal from man, 6 percent, from wild pig and man, 3.6 percent from warthog and 1.2 percent, from wild pig. Although maximum care has been taken to avoid flies from the catching party, it is probably that some might have fed on the fly boys.

Contrary to the arguments put forward by Glasgow (1963) and Weitz (1963), Ford (1969) elegantly demonstrated that in Nigeria G. m. submorsitans would readily feed on man rather than on a stationary or moving ox when its fat reserve is near exhaustion. Host selection is sometimes dependent on the availability of hosts(s) rather than on the preference. Tsetse species may be specialized feeders on the predominant host(s) within their localized habitats, but when necessary, they can also adapt to any available hosts for survival (Oniah, 1980; Ford, 1969). The latter author also pointed out that laboratory colonies of tsetse flies have been successfully maintained on goats, rabbits and guinea pigs. They can even be fed on blood through artificial membranes.

From the hunger category data (Table 6, 13, 14 & 15) the majority of the tsetse flies of Finchaa area seem to be under hunger stress during most months. This might be the reason why they readily feed on human beings, who frequently move from the plantations in the lowland area to the town of Finchaa on top of the escarpment and also on the people who work in the various development schemes. This observation for Glossina morsitans ugandensis is in conformity with explanations given for the feeding behaviour of other G. morsitans species by Ford (1969) and Oniah (1980).

If the catholic feeding behaviour of G.m. ugandensis is maintained, it could be of significance to the epidemiology of human trypanosomiasis. Moreover, the ease with which G.M. ugandensis feeds on human blood could be of particular public health importance if the causative organisms of sleeping sickness in East Africa (T.b. gambiense) are introduced into Finchaa by means of migrant labourers. Sleeping sickness is known to exist in the neighbouring administrative regions, Illubabor (Hutchinson, 1970). If this happens, then the vast agricultural development schemes, the giant hydro-electric power station and the sugar factory could be easily jeopardized.

The intermittent feeding observed by G. morsitans ugandensis on wild pig, warthog and man could be of importance in transmission of the disease from animals to the fly and eventually to man. This is of great significance in the epidemiology of human trypanosomiasis (Weitz, 1963).

In the present study the blood-meals obtained by G.m. ugandensis from warthog and wild pig are too few to be compared with other works elsewhere (Weitz, 1963; Mulligan, 1970; Glasgow, 1963; Ford, 1971; FAO, 1979). Such deviation may be a result of the on-going development programmes in the Finchaa Valley which may have an influence in remote and inaccessible places. Reduction in the number of wild suids and bovids in this area as a result of hunting by the labourers should not be ruled out.

6.8 - Infection Rate

A. In tsetse flies

The infection rate observed in the present study in Glossina morsitans ugandensis is low (0.5%). This is extremely low for morsitans group flies. In other places the infection rate in morsitans group is normally in the range of 15-20% (Mulligan, 1970; FAO, 1982; Ford, 1971). The low infection rate in the flies in the present study could be that:

- (i) the active transmission foci might have been restricted to certain isolated pockets. Most of the flies outside these pockets would be clean (FAO, 1982).
- (ii) the number of flies dissected were not large enough, especially when one compares the present work with that of others (Mulligan, 1970; Glasgow, 1963).
- (iii) the tsetses have been collected at relatively higher altitudinal ranges. And According to Mulligan (1970) there is some relation with temperature. Because altitude is an indirect indicator of temperature, flies collected at higher altitudes might have been unable to harbour infection (Molyneux, 1980).

B. In Cattle

The infection rate in cattle is relatively high (33%) when compared with that obtained by Langridge (1976). The isolated parasites were identified as T. vivax and T. congolense (FAO, 1982, Davies in putetal, 1980).

Some of the farmers in the highland take their cattle down to the valley for a few days to farm the land. It is possible that some of these cattle might have been infected in the valley on such occasions.

7 - CONCLUSIONS

The present investigation has revealed the mono-species composition of the tsetse flies of the Fincha River Valley. In addition, the pattern of seasonal fluctuation and diurnal periodicity of the flies has been established. This information is vital before embarking on control and/or eradication of these flies. The first could be during the wet/warm season when the fly population reaches its peak. At this particular season of the year control should be waged in order to suppress the fly population. The second could take place in the hot/dry season when integrated methods should be employed to make the valley free of the flies.

Furthermore, the biphasic diurnal periodicity of the fly could be a relevant factor in indicating appropriate times of application as well as the type of insecticide to be used.

The study demonstrated the unique eco-distribution of the flies in the valley. This would be relevant for any tsetse control programme in the future.

Bush-fires are generally undesirable, since they implant a serious ecological disturbance in a biosystem. However, due to it, the fly-population and the fly-belt collapse sharply for a while. The tsetse flies may concentrate in specific habitats during forest-fire. Apparently, this would be the best time to control or eradicate the tsetse flies. The flies that concentrate near the streams and brooks could be treated with insecticides by aircraft or from the ground sprays.

The apparent density (A.D.) of the tsetse flies could be used as a base-line index for future studies.

Knowledge of the physiological conditions and the sex ratio of the G. m. ugandensis of the Fincha River Valley would throw light onto the understanding of their biology and behaviour in this unusual habitat. Moreover, the age structure of this species would help to predict and extrapolate the future fly-population trends and risk of infection.

The blood-meal analysis results exhibited the unusual opportunistic feeding behaviour of G. morsitans ugandensis. The present finding showed man to be

the most important host around the survey area. This may render the area epidemiologically dangerous and may call for active medical surveillance.

The cattle which suffer from bovine trypanosomiasis on the edge of the escarpment deserve treatment. The cattle we find here not only serve for ploughing the land but are also the meat and milk source for the people in the highland as well as for the labourers in the Valley.

In the future, mark-release and recapture methods should be used to estimate more accurately the fly density of the area. Future work should investigate diurnal and nocturnal resting sites of the fly, as this would be of paramount importance to understand the habits of the vector as well as to carry out eradication programmes in the most efficient and economical way.

In order to make the work more complete the infection rate of the flies along the escarpment should be determined. Moreover, the effect of the new plantation and settlement schemes on the vector (flies) population in the Valley has to be assessed.

REFERENCES

- Andrewartha, H.G. and Birch, L.C. (1974). The Distribution and Abundance of Animals. University of Chicago Press, Chicago. 782
- Asticraft, M.T. (1959). The importance of African wild animals as the reservoirs of trypanosomiasis. E. Afr. Med. J., 30, 31, 36
- Baker, J. R. (1968). Trypanosomes of wild animals in the neighbourhood of the Serengeti National Park. Symp. Zool. Soc. Lond., 24, 147-158.
- Baker, J.R., McConnell, E.C., Kent, D.C. and Hardy J. (1970). Human trypanosomiasis in Ethiopia. Trans. R. Soc. Trop. Med. Hyg., 64, 415.
- Baldry, D.A.T. (1964). Observations on the close association between *Glossina tachinoides* and domestic pigs near Nssuka, E. Nigeria. Ann. Trop. Med. Parasit., 58, 58-59.
- Balis, J. and Bergeon, P. (1970). Etude sommaire de la Repartition des Glossines dans l'Empire de l'Ethiopie. Rev. Elev. Med. Vet. pays trop., 23-24
- Bannister, G.L. (1957). Report to the Government of Ethiopia on Livestock Disease Control F.A.O., Rome.
- Boreham, P.F.L. (1972). Recent developments in, and possible future applications, of the identification of Blood-meals in vectors of African trypanosomiasis. Unpublished mimeographed document, WHO/TRYP/WP/72, 6-7.
- British Overseas Development Administration (1976). An application for British Technical cooperation by the Ethiopian Government. The establishment of a Training Centre for Biologists, Tsetse officers and Assistant Tsetse Officers, London.
- Brumpt, E. (1903). Statistique medecale faite dans un voyage a travers l'Afrique tropicale (Note preliminaire) C.R. de l'Ass. Franc - pour L'Avanc. des Sciences. Congres d'Angers.

- Bursell, E. (1957). The water balance of tsetse flies. Trans. R. Ent. Soc. Lond., 111, 205-235.
- Bursell, E. (1969). The behaviour of tsetse flies in relation to problems of sampling. Proc. R. Ent. Soc. Lond., (A), 36, 9-20.
- Bursell, E. (1970). Dispersal and concentration of Gelossina. In: The African Trypanosomiasis (Ed. by Mulligan H.W.), 950. Allen and Unwin, London.
- Buxton, P.A. (1955). The Natural History of Tsetse Flies. Lond., Sch. Hyg. and Trop. Med. Memoir No. 10' H. K. Lewis, London.
- Caccavella, A. (1938). Prime Osservazioni sulle infezioni degli animale domestiche delle vollega. Nouva veterinaria, No. 4, 13-17.
- Challier, A. (1965). A melioration de la methode de determination de l'age physiologique des glossines. Etudes faites sur Glossina palpalis gambiensis vander plank, 1949, Bull. Soc. Path. Exot.; 58, 250-259.
- Challier, A. (1977). Trapping technology. In: Tsetse: The future for Biological Methods in Integrated Control (Ed. by Laird M.). IDRC-077e, Ottawa.
- Challier, A., Eyraud, M, Lafaye, A. and Laveissiere, C. (1977). Amelioration due rendement du piege biocnique pour glossines (Diptera, Gelossinidae) par l'emploi d'un cone inferieur blue. Cah. OSTROM ser. Ent. Med. et Parasitol. XV, 283-286.
- Challier, A. and Laveissiere, C. (1973). Un nouveau piege pour la capture des glossines (Gelossinina; Diptera, Muscidae): Description et essais sur le terrain. Cah. ORSTOM, ser Ent. Med. et Parasitol. XI, 251-267.
- Chalmers, A.I. and King, H.H. (1913). Distribution of Gelossina Longipennis Corti J. Trop. Med. Hyg., 16, 14-15.

- Corti, E. (1895). Esplorazione del Gauiba edei suoi affluenti compiuta dal. Cap. v. Bottego durante gli anni 1892 - 1893 Et. Heri. Ann. Mus. C.V. Genova. 10-11.
- Domizo, D (1937). Nagana nella valle del Didessa in Abissinia. Arch. Ital. Sc. Med. Col. Purass., 18, 129-130 and 193 - 195.
- Donaldson, S.A. (1897). Through unknowns African countries. Edward Arnold, London and John Wilsen and Co., Cambridge, U.S.A.
- FAO (1982) , Training Manual for Tsetse Control Personnel 1-105.
- Ford, J. (1971). The role of Trypanosomiasis in African Ecology. A study of the Tsetse fly problem. Clarendon press, Oxford. 568.
- Ford, J. (1969). Feeding and other response of tsetse flies to man and ox and their epidemiological importance. Acta. Trop., 26, 249-264
- Ford, J. and Katendo, K.M. (1977). The distribution of Tsetse Flies in Africa +6 (OAU/ISTRIC, Map, Nairobi).
- Ford, J., Makin, M.J. and Grimble (1976). Trypanosomiasis Control Programme for Ethiopia. Clarendon Press, Oxford, 496.
- Fuller, G.K. (1978). Distribution of Gelossina (Diptera, Gelosinidae) in south western Ethiopia, Bull. Ent. Res., 68, 299-306.
- Gatehouse, A.G. (1972). Host - finding behaviour of tsetse flies. In: Behavioural aspects of parasite transmission, E.V. Canning and C.A. Wright (year). Zool. J. Linn. Soc. 51 Suppl., 1, 83-95.
- Ghidini, G.M. (1938). Le glossine dell Africa orientale italiana. Riv. Biologia Colon., 432-447
- Glesgow, J.P. (1963). The Distribution and Abundance of Tsetse. Pergamon press, Oxford. 241.

- Godfrey, D.G. (1961). Types of Trypanosoma congolense. II. Differences in the course of infection. Ann. Trop. Med. Parasit., 55, 30-31.
- Hoare, C.A. (1970). The Mammalian trypanosomes of Africa and systematic description of mammalian trypanosomes of Africa. In: The African Trypanosomiases (edited by Mulligan (year), publishers, ok. 610.
- Hoare, C.A. (1972). The Trypanosomes of mammals. Blackwell Scientific publications, London. 401-610.
- Hutchinson, M.P. (1970). Human Trypanosomiases in south west Ethiopia. Ethiop. Med. J., 3-4.
- Jackson, C.H.N. (1946). Male wing fray degener. Bull. Ent. Res., 37, 291-292.
- Jackson, C.H.N. (1930). Contributions to the bionomics of Glossina morsitans. Bull. Ent. Res., 21, 491-527.
- Jaenson, T.G.T. (1978). Reproductive biology of the tsetse fly Glossina pallidipes Austen (Diptera, Glossinidae), with special reference to mating behaviour.
- Acta Universitatis Upsaliensis. (Abstracts of Upssala Dissertations from the faculty of Science). 479, 3-35.
- Jordan, A. M. (1965). The hosts of Glossina as the main factor affecting trypanosome infection rates of tsetse flies in Nigeria. Trans. R. Soc. Trop. Med. Hyg. 59, 423-431.
- Kunert, H. (1956). In: World Atlas of Epidemic Diseases, Part 2, Hamburg, Falk (Ed) 131.
- Lamberecht, F.L. (1964). Aspects of evolution and ecology of tsetse flies and trypanosomiases in the prehistoric African environment. J. Afr. Hist. 5, 1-24.
- Lambercht, F.L. (1980). Ecological and physiological factors in cyclic Transmission of African Trypanosomiasis. Insect Sci. Application, 1, 47-54.

- Langridge, W.P. (1975). The design and operation of the 'Langridge' tsetse fly trap. Proc. Intern. Sci. Coun. Tryp. Res., 14th meeting, Dakar. Senegal Pub. No. 109, 227-281.
- Langridge, W.P. (1976). A Tsetse and Trypanosomiasis Survey of Ethiopia, 98
- Lewis, D.J. (1951). Notes on tsetse flies in the Anglo-Egyptian Sudan, Sudan Notes and Records, 32, 36-37.
- Livestock Division (1962). Report on Livestock (cattle) survey in southern Ethiopia, unpublished document of Ministry of Agriculture, Addis Ababa, Ethiopia, 1-30.
- Machado, B. (1954). Revision systematique des glossines du groupe Palpalis. pub. du Museu de Dundo, Angola.
- MacLellan, K.J.R. and Cock, M.G. (1972). The resting behaviour of Glossina morsitans newst. in the Northern Guinea vegetation zone in relation to control using insecticides. Entomologist, 105, 144-156.
- McConnel, E.C., Hutchinson, M.P. & Baleer, J.R. (1970). Human Trypanosomiasis Ethiopia. The Gilo River. Trans. R. Soc. Trop. Med. Hyg., 64, 5-6.
- Muirhead - Thomson, R. (1968). Ecology of Insect Vector Populations Academic Press, London and New York, 8-30.
- Mulligan, H.W. (1970). The African Trypanosomiases. Allen and Unwin, London. 950.
- Molyneux, D.H. (1980). Animal Reservoirs and residual 'Forci' of Trypanosoma brucei gambiense sleeping sickness in west Africa. Insect Sci. Application, 1, 55-63.
- Nash, T.A.M. (1937). Climate, the vital factor in the ecology of Glossina. Bull. Ent. Res., 28, 75-127.
- Nash, T.A.M. (1969). Africa's Bane: The Tsetse Fly, Collins, London. 244.

- Onyiah, R.J. (1980). Hosts of tsetse flies. Insect. Sci. Application, 70-75.
- Otieno, L.H. (1973). Trypanosoma (Trypanozoon) brucei in the haemolymph of experimentally infected young Glossina morsitans inoculated into the tsetse haemocoel. Acta trop., 33, 143-150.
- Otte, E. (1961). Report No. 1426 on the Control of Livestock Diseases. F.A.O., Rome.
- Ouazza, M. (1956). Contribution a l'etude des dipteres vulnerants de l'empire d'Ethiopie. JV. Glossines. Bull. Soc. Patts. Ecol., No. 1956, 204-208.
- Peck, E.F. (1959). Report No. 1447 on Animal Disease control, F.A.O., Rome. 6.
- Pegram, R.G. and Scott, J.M. (1976). The Prevalence and Diagnosis of Trypanosoma evansi in camels in Southern Ethiopia. J. Trop. Anim. Hlth. Prod., 8, 3-10.
- Pollack, J.J. (1982). Training Manual for tsetse control personnel (vols. I, II and III). FAO, Rome.
- Putt, S.N.H. (1980). Research on social and economic implications of Trypanosomiasis control (A study of its impact on livestock production and rural development in northern Nigeria). Veterinary Epidemiology and Economics Unit, Department of Agriculture and Horticulture, University of Reading. Study no. 25, 1-250.
- Randolph, S.E. and Rogers, D.J. (1981). Physiological correlates of the availability of Glossina morsitans Centralis Machado to different sampling methods. Ecological Entomology 6, 63-77.
- Robson, J. (1971). Trypanosomiasis in domestic stock in Lambe valley, south Nyanza, Kenya. Unpublished document, WHO/UNDP Project Kenya 3 2301 (0041).

- Rogers, D.J. (1972). Studies on the mating of Glossina Pallidipes Austen.
I: The age at mating. Ann Trop. Med. Parasitol., 66, 515-523.
- Rogers, D.J. (1977). Study of a natural population of Glossina fuscipes
fuscipes Neustead and a model of fly movement J. Anim. Ecol., 46,
309 - 330.
- Rogers, D.J. (1979). Tsetse population dynamics and distribution; a new
analytical approach. J. Anim. Ecol., 48, 825-849.
- Saunders, D.S. (1960). The ovulation cycle in Glossina morsitans
Westwood (Diptera: Muscidae) and a possible method of age
determination for female tsetse flies by the examination of their
ovaries. Trans. R. Ent. Soc., Lond., 112, 221-238.
- Saunders, D.S. (1962). Age determination for female tsetse flies and the
age composition of samples of Glossina pallidipes Aust., G. palpalis
fuscipes newst. and G. brev. palpalis Newst. Bull Ent. Res., 53,
579-595.
- Scott, J. M. and Pegram, R.G. (1976). Observations over a three year period
on the maintenance of a herd of plough oxen on the Augar Challenge.
(Tsetse Trypanosomiasis survey section Report to the Ethiopian
Government, unpublished document Addis - Ababa, Ethiopia).
- Scott, J. M. (1975). An interim report on the bovine and camel trypanosomiasis
situation in the Negele (Borana) region, Sidamo (Ethiopia). 1-8.
- Turner, D.A. (1980). Tsetse ecological studies in Niger and Mozambique
I. Population sampling. Insect Sci. Application, 1, 9-13.
- Vale, G.A. (1974). The responses of tsetse flies (Diptera, Glossinidae)
to mobile and stationary baits. Bull. Ent. Res., 64, 545 - 588.
- Vale, G. M. (1977). Feeding responses of tsetse flies to stationary hosts.
Bull. Ent. Res., 67, 635-649.

Weitz, B. (1963). The feeding habits of Glossina. Bull. Wld. Hlth. Org.,
28, 711 - 729.

WHO/FAO (1969). African Trypanosomiasis (TFS) 3-45.

WHO (1978). African Trypanosomiasis (TRCE) 1-50.