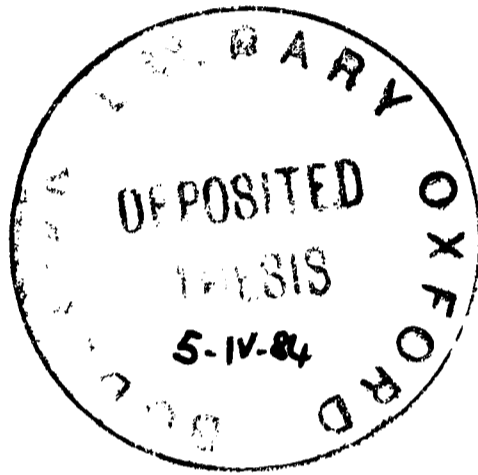


TSESTE CONTROL, AGRICULTURAL EXPANSION  
AND ENVIRONMENTAL CHANGE IN NIGERIA.



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Thesis submitted to the Board of the Faculty of Biological and  
Agricultural Sciences for the Degree of Doctor of Philosophy.

Trinity Term 1983.

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A brief account of the history of government organised tsetse and trypanosomiasis control in Nigeria is presented, and major features of the tsetse eradication programme are summarised.

The achievements are considered in the context of widespread environmental change, brought about by an increasing human population, and a long term process of agricultural expansion, which have resulted in an overall reduction in natural tsetse habitats and hosts, and led to a general decline in tsetse populations.

A comparison of two areas, one within, and the other outside the tsetse eradication zone, showed that they had both experienced similar rates of change in land use, and available information indicated that human and cattle populations had also increased at similar rates.

The present day distribution and abundance of tsetse and cattle in a region of the Nigerian sub-humid zone, not yet reached by the tsetse eradication programme, are described. In the virtual absence of wildlife, abundance of cattle, and concentration of the two riverine tsetse species at crossing points, it was concluded that tsetse were largely dependent on cattle and/or man for their survival.

The low density of riverine tsetse populations, their restricted distribution and their low infection rates, combined with Fulani herd management practices, which limited the period of contact between tsetse and cattle, indicated that under the prevailing conditions, trypanosome challenge was likely to be very low. It is suggested that this situation was typical for many areas within the sub-humid zone, and that in the future, similar conditions are likely to become even more widespread.

It is concluded that, whilst government trypanosomiasis control programmes must have contributed to the general decline of the disease which has taken place, the environmental context within which they were mounted, has changed significantly. Over the past fifty years human population has almost certainly increased three or four fold, and the extent and intensity of both farming and hunting have increased commensurately. This has resulted in an overall reduction in natural tsetse habitats and hosts, which has led to a decline in vector populations. It is argued that this, together with a trend for Fulani and their cattle to become more sedentarised, has brought about a fundamental change in the balance of relationships in the vector-host-disease complex, which has favoured the development of appropriate immune responses in Fulani cattle, and the selection of less pathogenic strains of trypanosome.

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PREFACE AND ACKNOWLEDGEMENTS.

A brief explanation of the background to this thesis is in order. In 1978, under the auspices of the then Ministry of Overseas Development, I joined a multidisciplinary team from the Veterinary Epidemiology and Economics Research Unit of Reading University attached to the Nigerian Federal Livestock Department, and collaborated with them on a study of the social and economic implications of trypanosomiasis control in northern Nigeria.

Subsequently I was seconded, as a Technical Cooperation Officer, for a three year period, to a newly created project for the Biological Control of Tsetse in Nigeria, managed by the Federal Department of Pest Control Services, and the joint division of the International Atomic Energy Agency and the Food and Agriculture Organisation of the United Nations. My responsibilities were to assist in the establishment of the project and the supervision of the field programme.

I am grateful to the organisations mentioned above for providing me with the opportunity of living and working in Nigeria, and thereby allowing me to study the history of tsetse and trypanosomiasis control, and gain first hand experience of the current field situation. However, the views and interpretations expressed in this thesis are my own, and do not necessarily reflect those of any of the organisations concerned.

I would also like to express my appreciation to the many individuals with whom I worked, for their support, encouragement and assistance: members of the BICOT project, especially the field staff; members of the Reading Team; the staff of the British High Commission in Kaduna; Kevin Milligan and Ralph von Kaufmann of the Sub-humid Programme of the International Livestock Centre for Africa in Kaduna; and David Rogers, my supervisor at Oxford.

Finally, I would like to thank my wife, for all her help, patience and understanding throughout.

" No condition is permanent."

Nigerian Mammy Wagon Slogan.

## 1 INTRODUCTION.

Africa is a vast continent of great diversity and potential. A major impetus for change is the rapid increase in human population that is taking place in all African countries. The phenomenon has given rise to national and international concern on a variety of issues, particularly over how to meet the ever increasing demand for more food, and better standards of health.

Improved agricultural productivity is a widely recognised priority. With the majority of Africa's population living in rural areas and dependent on farming, greater attention is being given to rural development in general and agricultural development in particular, which has been described as the key to more rapid and equitable growth (World Bank, 1979).

The goal of improved agricultural productivity raises many important questions concerning the nature of agricultural development, and how it may be achieved. For instance: What priorities should be given to the various forms of arable and livestock production? Is mixed farming to be encouraged? Should draught animals be utilised, or is mechanisation more desirable? What balance should be struck between agricultural production for local consumption, and that for export and foreign exchange earnings? What emphasis should be placed on the promotion of small stock: sheep, goats, pigs, rabbits and chickens, as opposed to cattle? Is beef or dairy production to be encouraged? What are the prospects for encouraging alternative forms of food production, such as fish or game farming? Indeed, are future human protein requirements to be met from animal or plant sources?

Medium to long term agricultural development planning must consider questions such as these, but in the short term, increased food production is likely to depend on a gradual process of upgrading existing forms of agriculture.

A wide range of farming systems have been described (Ruthenberg, 1976), with various degree of integration of crop and animal husbandry (Purseglove, 1968 and 1972; Dahl and Hjort, 1976; Williamson and Payne, 1978). The system prevailing in a particular area, or practised by a particular group of people, is the result of a long and continuing process of adaptation to local conditions. Attempts to change and improve upon traditional farming systems, or practices, have frequently met with only limited success, because of failure to appreciate fully the significance of the many factors involved in the establishment and maintenance of existing systems.

Numerous constraints to agricultural development in Africa have been identified (Allan, 1965; Grigg, 1970; Ruthenberg, 1976), including the presence of tsetse, and the prevalence of animal and human trypanosomiasis.

Tsetse transmitted trypanosomiasis have been the subject of prolonged scientific study, dating back to the turn of the century, when Bruce (1895) first established the vector-disease relationship in cattle, and a series of widespread and devastating epidemics of human sleeping sickness took place. A diverse, complex and voluminous literature has been generated; major works of reference and more recent reviews include: Buxton (1955); Glasgow (1963); WHO (1963); Lumsden (1965 & 1970); Mulligan (1970); Ford (1971); Hoare (1972); Finelle (1973a & b, 1974); Jordan (1974); Laird (1977); Losos and Chouinard (1979); and MacLennan (1980 & 1981).

The causative agents of the complex of diseases, collectively known as the trypanosomiasis, are single-celled, generally flagellated, protozoan parasites, usually found in the blood and other tissues of vertebrates. The genus Trypanosoma has a world-wide distribution, and a variety of vectors are involved in transmission of the different diseases, which have been classified on the basis of their mode of transmission. Infective forms of the Stercoraria typically develop in the mid- and hind-gut of the vector and are transmitted by faecal contamination. In contrast, the Salivaria develop infective forms in the proboscis and salivary glands, and are transmitted by salivary inoculation during feeding.

The trypanosomiasis transmitted by tsetse are all of the Salivaria group, which has been divided into three subgenera, based on their development cycle within the vector: Duttonella, developing exclusively in the proboscis, e.g. T.(D.) vivax; Nannomonas, developing in the proboscis and mid-gut, e.g. T.(N.) congolense; and Trypanozoon developing in the mid-gut and salivary glands, e.g. T.(T.) brucei.

Tsetse are ovoviviparous, haematophagous Dipterans, belonging to the genus Glossina, and are found exclusively in Africa. 22 species and 14 sub-species are generally recognised, which on morphological grounds (confirmed by chromosomal pattern) have been divided into three major groups: fusca; palpalis; and morsitans. Although the genus is geographically widespread over the continent between latitudes 15°N and 28°S, and one or more species have been found in 36 countries, many species have a relatively limited distribution (Ford and Katondo, 1977). Members of the fusca group tending to be associated with more humid environments and forest habitats; while

members of the palpalis group are generally confined to waterside habitats; and members of the morsitans group are usually found in areas of drier savanna vegetation.

Disease control measures, including chemotherapy, chemoprophylaxis and vector control, have much improved since 1925, when the East African Commission reported that "the ravages of the tsetse-fly are the greatest single menace to development of tropical Africa, and constitute one of its most serious problems" (Ormsby-Gore, 1925). Nevertheless, as recently as 1976, a joint panel of experts appointed by the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO) declared that: "Trypanosomiasis in Africa are still one of the most serious threats to the health of man, and a serious obstacle to development of agricultural industry" (FAO, 1979).

Both organisations have recently expanded their activities in the field of trypanosomiasis research and control. Following a resolution of the 1974 World Food Conference, FAO has initiated a long term programme for the control of animal trypanosomiasis in Africa. Extensive operations for the control of tsetse, by the aerial application of insecticide, have been proposed within some five million square kilometers of the drier savanna regions; and it has been suggested that the rearing of trypanotolerant cattle should be promoted over some two million square kilometers of the wetter savanna regions (FAO, 1974).

The justification for this programme has been questioned in many circles, and in particular the necessity for large scale tsetse control operations. The extensive application of insecticide has by no means been universally accepted. Linear (1981 and 1982); Ormerod (1976 and 1979) and de Vos (1978) have been particularly outspoken critics. They have emphasised not only the environmental pollution hazard of widespread insecticide application, but also the detrimental environmental consequences of tsetse elimination: overstocking, overgrazing and land degradation. In addition, they have stressed that tsetse and trypanosomiasis play an important conservation role, by inhibiting human settlement and the introduction of cattle.

These arguments have been countered by Na'isa (1976), Jordan (1979) and Putt (1979), who have pointed out that very low dosages of insecticide are required to control or eradicate tsetse, and that the amounts applied are small in comparison with those used against other agricultural pests. They have also argued that rather than exacerbate the problem of overstocking and overgrazing, tsetse control, by making more land available for grazing, if anything, was likely to reduce the risk of land degradation. Jordan (1979) has suggested that tsetse and trypanosomiasis control measures provide a means of better management of natural resources, and more effective implementation of agricultural development and land use plans.

The debate over the desirability and feasibility of a continental programme for the control of animal trypanosomiasis is likely to continue. Much depends on ones views of agricultural development, and what priority should be given to livestock production in general, and to the rearing of cattle in particular. Limited national trypanosomiasis control programmes have existed for many years in various countries, but local conditions, priorities and methodologies

have differed considerably. FAO's role can be seen as one of attempted coordination, and the proposed programme as a means of generating renewed interest in an old problem, in order to raise international funds to support control operations and promote cattle husbandry.

Government organised tsetse control or eradication programmes, using insecticides, have been mounted in 18 African countries: Botswana; Cameroon; Chad; Central African Empire; Ivory Coast; Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Rwanda; South Africa; Tanzania; Uganda; Upper Volta; Zambia; and Zimbabwe (FAO, 1977).

Of these, operations in Nigeria, covering some 200,000 square kilometers, have been by far the most extensive. In addition Nigeria has one of the longest and most concerted records of research and control of both human and animal trypanosomiasis. This thesis attempts to outline the course of tsetse and trypanosomiasis control in Nigeria, and examines the changing environmental context within which it has taken place.

## 2 OVERVIEW OF TSETSE AND TRYPANOSOMIASIS CONTROL IN NIGERIA.

### 2.1 Setting.

The history of Nigeria has been told by Crowder (1978), and described in a West African context by Ajayi and Crowder (1974). Her more recent past has been particularly eventful. Following independence which was gained in 1960, the former administrative system of three regional governments was first changed in 1963 by the establishment of a fourth region; which subsequently led to the creation of 12 states in 1967, and further sub-division in 1976 to form the 19 states that exist today. A military government took power in 1966. The Biafran civil war was fought between 1967 and 1970. Civilian rule was resumed in 1979. Perhaps most significantly of all, during the past 25 years Nigeria has become a major oil producing and exporting country.

As a result of this latter development Nigeria now has the highest Gross National Product of any black African country. Despite this, because of her large human population, variously estimated to be between 80 and 100 million, average per capita GNP remains relatively low in global terms, and the World Bank (1979) categorises Nigeria as a "middle income country".

Nigeria occupies a land area of some 924,000 square kilometers, over which her ethnically highly diverse population is far from evenly spread. Human population growth rate is ill-defined, but often assumed to be around 2.5% per annum, although there are reasons to believe that it could well be higher. Food imports have increased substantially, and the importance of increased agricultural production

and improvement of farming methods has repeatedly been emphasised by the Federal Government. Despite the uncertain reliability of many published statistics it is widely accepted that the majority of the Nigerian population (82%, according to the World Bank, 1979) remains rural and dependent on agriculture. The proportion is believed to be falling due to urban migration, but the overall size of the rural population continues to grow.

A selection of the many recently published text books, describing the West African environment as a whole, or dealing specifically with Nigerian geography, climate and agriculture, is listed in the general bibliography.

The control of trypanosomiasis has long been a priority of Nigerian governments. The history of scientific research and organised control dates back to the early years of the present century, when the first tsetse and trypanosomiasis surveys were carried out.

Since then much has been accomplished. Through research and field experience, knowledge and understanding of the nature of trypanosomiasis has greatly improved; strategies and techniques have been developed to combat the disease; major vector control and eradication programmes have been mounted; a large amount of information has accumulated in government reports and files; and numerous scientific papers have been published on various aspects of the disease and its control.

The literature and status of the disease have been reviewed at various stages in the past: Davey (1948); Nash (1948); Duggan (1962); Glover

(1965); MacLennan (1968); Ford (1971); Davies (1977); and most recently by Putt et al. (1980). It is not the intention that this chapter should present a further review of an extensive literature, rather its purpose is to set the scene, and highlight some of the major features of the control of trypanosomiasis in Nigeria.

## 2.2 Organisational History.

In 1921, following a proposal from the Imperial Bureau of Entomology, the Tsetse Investigation Department of Northern Nigeria was established. Its function was initially intended to be primarily one of research, but during the late twenties the department was completely reorganised and incorporated within the Medical Department and became known as the Sleeping Sickness Service, which played a major role in control of the human disease.

In 1937 the Tsetse Control Section of the of the Sleeping Sickness Service was formed.

In 1924 the Veterinary Department opened its main veterinary laboratories at Vom on the tsetse free Jos plateau and subsequently also established the headquarters of the Veterinary Services there. The function of the laboratories was to carry out research into animal disease and assist disease control in the field. Initially its primary task was to produce vaccine against rinderpest, but research on cattle trypanosomiasis was also an important aspect of the work. These organisations at Vom formed the basis of what has now become the National Veterinary Research Institute.

In 1948 the West African Trypanosomiasis Research Institute (WAITR) was established at Kaduna and Vom. It took over responsibility for research work on all aspects of human and animal trypanosomiasis, but had no disease control function. This continued to be carried out by the Medical Department's Sleeping Sickness Service and the Veterinary Department's animal health teams. After independence, in 1964, WAITR became the Nigerian Institute for Trypanosomiasis Research.

In 1953 a specific Veterinary Tsetse and Trypanosomiasis Unit was established, and began work on what was to become an extensive programme of tsetse eradication.

In 1969 the Veterinary Tsetse and Trypanosomiasis Unit and the Sleeping Sickness Service were amalgamated to form the Tsetse and Trypanosomiasis Division, which came under the Federal Livestock Department.

In 1979 the Tsetse and Trypanosomiasis Division was merged with a number of smaller agricultural units and a new Federal Department of Pest Control Services was created.

## 2.3 Tsetse.

### 2.3.1 Species Distribution.

Eleven species of Glossina have been found in Nigeria and are listed in table 2.1. The distribution of the three species groups has been broadly linked to general vegetation types: the forest dwelling fusca group; the palpalis group which is associated with riverine vegetation and the savanna dwelling morsitans group (Ford, 1971).

TABLE 2.1 GLOSSINA SPECIES AND SUBSPECIES FOUND IN NIGERIA.

<u>fusca</u> group:	<u>G. fusca congolensis</u> ; Newstead and Evans, 1921. <u>G. haningtoni</u> ; Newstead and Evans, 1922. <u>G. medicorum</u> ; Austen, 1911. <u>G. nigrofusca nigrofusca</u> ; Newstead, 1910. <u>G. tabaniformis</u> ; Westwood, 1850.
<u>palpalis</u> group:	<u>G. caliginea</u> ; Austen, 1911. <u>G. pallicera pallicera</u> ; Bigot, 1891. <u>G. palpalis palpalis</u> ; Robineau-Desvoidy, 1830. <u>G. tachinoides</u> ; Westwood, 1850.
<u>morsitans</u> group:	<u>G. longipalpis</u> ; Wiedemann, 1830. <u>G. morsitans submorsitans</u> ; Newstead, 1910.

TABLE 2.2 PERCENTAGE OF GLOSSINA BLOOD MEALS FROM DIFFERENT HOSTS.

	<u>G. palpalis</u>	<u>G. tachinoides</u>	<u>G. longipalpis</u>	<u>G. morsitans</u>
sample size*:	226	426	872	1067
<u>Primates</u>				
Man	26	30	2	13
Others	2	13	0	3
<u>Suids</u>				
Warthog	1	1	0	48
Others	4	1	4	11
<u>Bovids</u>				
Cattle	5	8	2	2
Sheep/goats	0	0	0	0
Buffalo	1	0	16	2
Bushbuck	7	1	74	4
Others	8	21	1	5
<u>Other mammals</u>	3	16	1	8
<u>Reptiles</u>	38	8	0	0
<u>Birds</u>	6	1	0	3

\*All samples collected in Nigeria (after Jordan et al, 1962), except for G. longipalpis which includes samples from elsewhere in West Africa (after Weitz, 1963).

TABLE 2.3 TRYPANOSOME INFECTION RATES OF COMMONER NIGERIAN TSETSE.

	<u>G. palpalis</u>	<u>G. tachinoides</u>	<u>G. longipalpis</u>	<u>G. morsitans</u>
<u>Overall:</u>	2 - 10	4 - 31	22	7 - 77
<u>Of which:</u>				
<u>T. vivax</u>	79 - 90	61 - 90	82	19 - 95
<u>T. congolense</u>	9 - 24	10 - 20	18	5 - 81
<u>T. brucei</u>	0 - 1	0 - 22	0.1	0 - 11

Derived from Ford (1971); Jordan (1961, 1964, 1965a and 1974).

Seven of these species: G. pallicera and G. caliginea of the palpalis group and the five members of the fusca group, are almost exclusively found in southern Nigeria.

Tsetse and trypanosomiasis control programmes have largely taken place in northern Nigeria, where the four remaining species occur: G. palpalis and G. tachinoides of the riverine group; and G. longipalpis and G. morsitans of the savanna group. Their general behaviour and ecology are summarised by Glover (1965) and Davies (1977).

Although the geographical range of each species is great, as indicated in figure 2.1, their actual distribution is often highly restricted, particularly near their northern limits, which are determined by species tolerance to temperature and humidity extremes. Further away from these limits, where climatic conditions are more favourable, especially during the wet season, distribution of all species is less restricted. Indeed, in more southerly parts of their range both G. tachinoides and G. palpalis may disperse well away from riverine vegetation to survive and breed in non-riverine habitats.

### 2.3.2 Hosts.

The survival of tsetse is dependent on regular feeding. Host identification is essential for understanding both species ecology and disease epizootiology. Jordan et al. (1961 & 1962) and Weitz (1963), respectively, have presented the results of blood meal analyses for different species of tsetse in Nigeria, and Africa as a whole.

FIGURE 2.1 : RANGES OF FOUR MAJOR TSETSE SPECIES IN NIGERIA  
( AFTER DAVIES, 1977 )

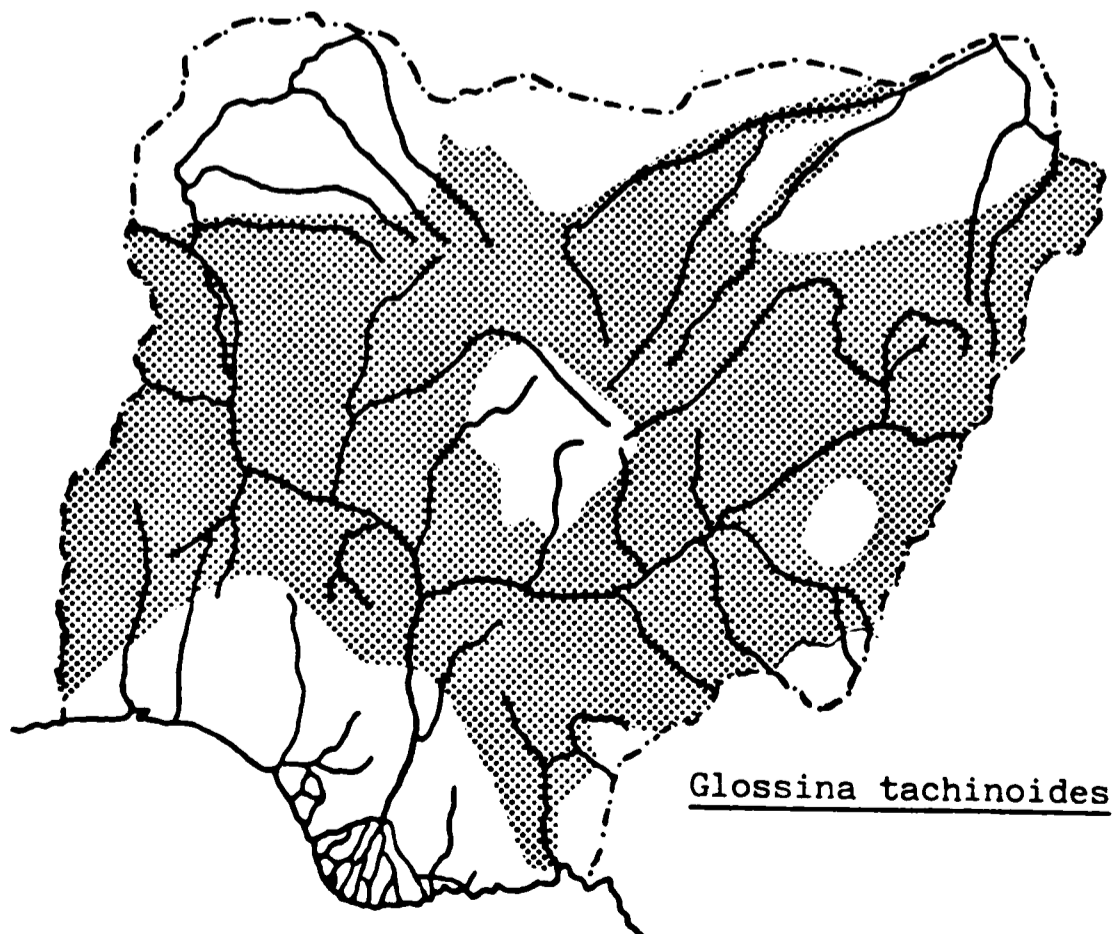
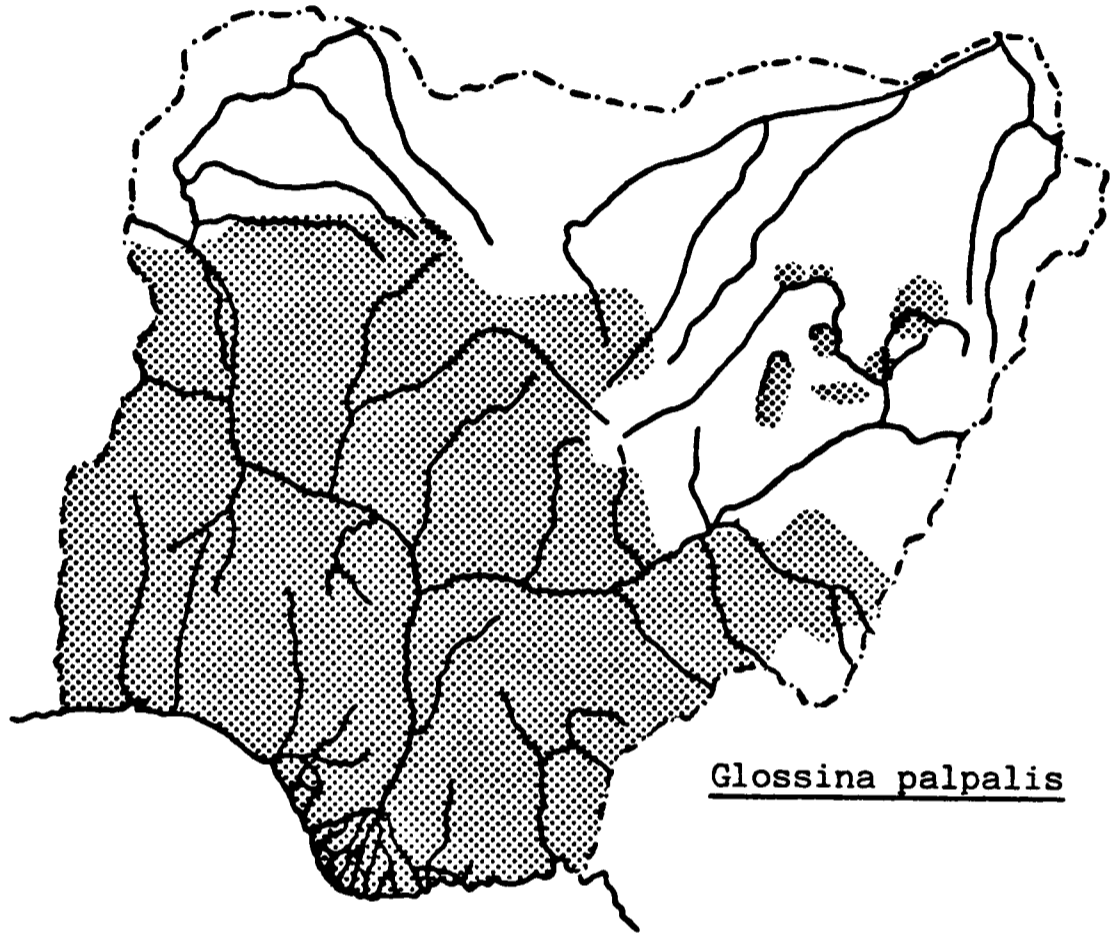


FIGURE 2.1 continued

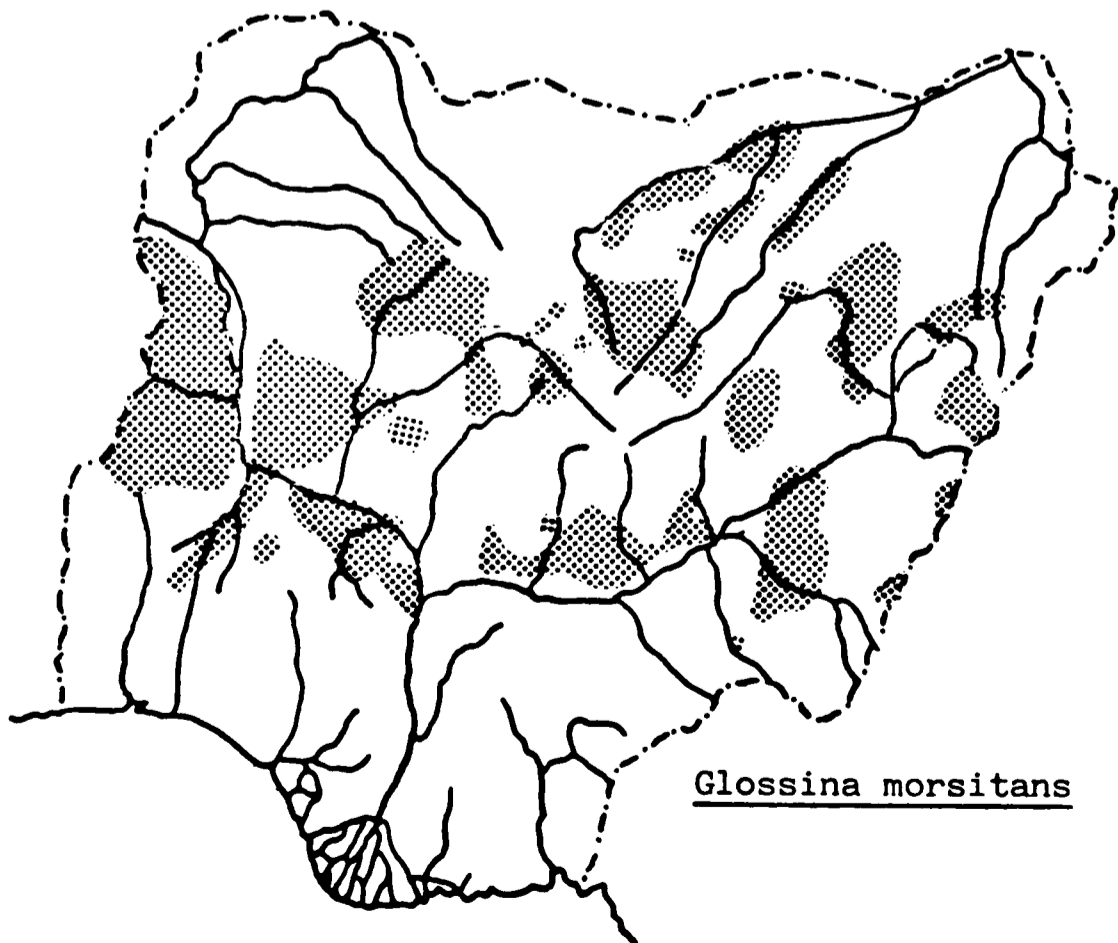
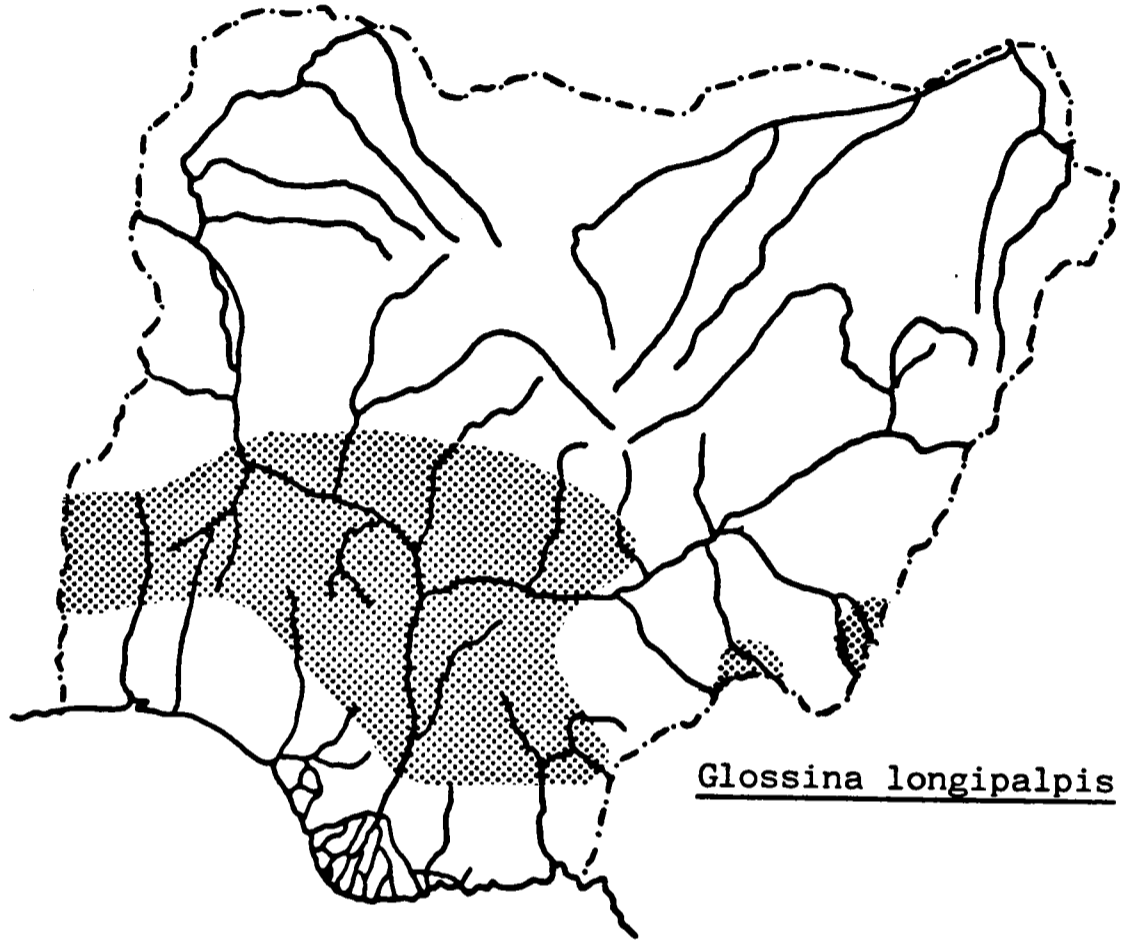


Table 2.2 summarises the hosts of the four major species of tsetse found in northern Nigeria. The most frequently identified blood meal sources of G. palpalis were from man and reptiles (probably the monitor lizard). For G. tachinoides man also appeared to be a major host, as were bovids and other mammals; reptilian blood meals were not as common as in G. palpalis. For G. morsitans suid blood meals, particularly from warthog, were most frequently identified, while man and other mammals were of lesser importance. The vast majority of G. longipalpis blood meals were from bushbuck.

Clearly major differences exist in the blood meal sources of each tsetse species, but as Weitz (1970) and Jordan (1974) have pointed out, the host proportions for a given tsetse species vary from locality to locality. The riverine G. tachinoides and G. palpalis are considered to be particularly adaptable and opportunistic feeders in the northern part of their range, whereas further south, Baldry (1964) has found G. tachinoides feeding almost exclusively on domestic pigs, and never on man. G. morsitans has, in the absence of wildlife, been found capable of surviving exclusively on cattle blood in the somewhat atypical circumstances of a regularly used trade cattle route in southern Nigeria (Jordan, 1965b; Baldry, 1969; and Riordan, 1976).

### 2.3.3 Infection Rates.

Tsetse infection rates show a wide range of variation, both from species to species of tsetse, and from species to species of trypanosome. Table 2.3 indicates the range of infection rates found in

the four tsetse species most commonly encountered in northern Nigeria.

T. vivax infections are usually most common, followed by T. congolense, with T. brucei being most infrequent. Jordan (1974) has reviewed the wide variety of factors influencing infection rates. As well as the actual method used to catch tsetse, which may provide biased population samples, they include:

maintenance temperature of puparia and adults - the higher the temperature, the higher the infection rate;

age of individual tsetse at the time of infective feed - younger flies being more readily infected than older flies;

period required by each species of trypanosome to complete development cycle within tsetse and produce mature infective forms - T. vivax having the shortest period and T. brucei the longest period;

age structure of tsetse population - the greater the average age the higher the infection rate;

host species, their infection rates, and their trypanosome reservoir capacity - bovids being primarily reservoirs of T. vivax and to a lesser extent T. congolense, whilst suids are primarily reservoirs of T. brucei and to a lesser extent T. congolense;

genetic differences in susceptibility to infection between different species of tsetse;

and finally, genetic differences in susceptibility to infection between different individuals/populations of the same species of tsetse.

#### 2.4 Human Trypanosomiasis.

Johnson and Lloyd (1923) considered sleeping sickness to be endemic over most of the Northern Provinces of Nigeria. Duggan (1962), however, has suggested that earlier Nigerian records indicated that at the dawn of the twentieth century human sleeping sickness existed in two primordial zones: one, within the Niger and Benue valleys, where the disease was essentially mild, chronic and endemic; and the other, along reaches of rivers draining into lake Chad, where periods of low

endemicity were disrupted by epidemics of a more acute form of the disease. (See figure 2.5). In the Benue and Niger valleys the major vectors of the disease were the riverine species G. palpalis and G. tachinoides, while in the Chad basin the major vector was G. tachinoides.

It is now generally recognised that human sleeping sickness is caused by forms of T. brucei with variable pathogenicity and virulence. Descriptions of the disease in man vary considerably; from very mild, almost symptomless self-curing cases; through chronic infections of low mortality; to severe acute cases, with or without central nervous system involvement and the classical "sleeper" characteristic, but having a high rate of mortality.

With such variable symptoms, the disease may not, therefore, always be easily recognised, and indeed relatively few cases were reported during the first 25 years of the century. Following the establishment of the Tsetse Investigation Department at Sherifuri on the Jamaari river in the Chad basin in 1921, and the recognition that an epidemic of sleeping sickness was taking place in the area, the department was reorganised to cope with the situation. In the early thirties an extensive disease surveillance and case treatment programme by field teams was initiated.

Survey and diagnosis was by lymph gland puncture, and microscopic examination of lymph and blood samples. The usual field treatment was by intravenous injection of various combinations of the drugs suramin and tryparsamide.

As progressively wider areas were covered, and more and more people examined, the number of detected and treated cases increased dramatically. (See figure 2.2). Resurveys also indicated that the epidemic was spreading into areas where the disease had not previously been known. Effectively the two primordial zones were merging. When it was realised that the epidemic was so widespread, a system of rural dispensaries was established to supplement the work of the mobile field teams, and 29 had been set up by 1937 (Glover, 1965).

Phenomenal numbers of people were examined during the programme: 1.25 million between 1931 and 1935; 1.5 million between 1936 and 1940; 0.5 million during the war years; nearly 4 million between 1946 and 1950; 6.25 million between 1951 and 1955; and some 8 million between 1956 and 1960. The highest overall incidence of the disease was recorded in 1935, when 20% of the 407,203 examined were found to be infected and received treatment. Since that peak there has been a marked and progressive decline in the prevalence of the disease, which had fallen to 1/1000 by 1960, and reached levels of 1/10,000 by 1976 (Putt et al., 1980).

This trend towards extremely low level endemicity on a national scale, masks numerous, generally small scale, local outbreaks that have occurred since the major epidemic of the thirties. The most serious occurred in the Chad basin. It began in the late forties, peaked in 1955, but was under control by the end of the decade.

Generally, however, in spite of the persistence of a few old foci in the Benue-Niger valley, the importance of the human disease has declined dramatically.

FIGURE 2.2 : CASES OF HUMAN SLEEPING SICKNESS

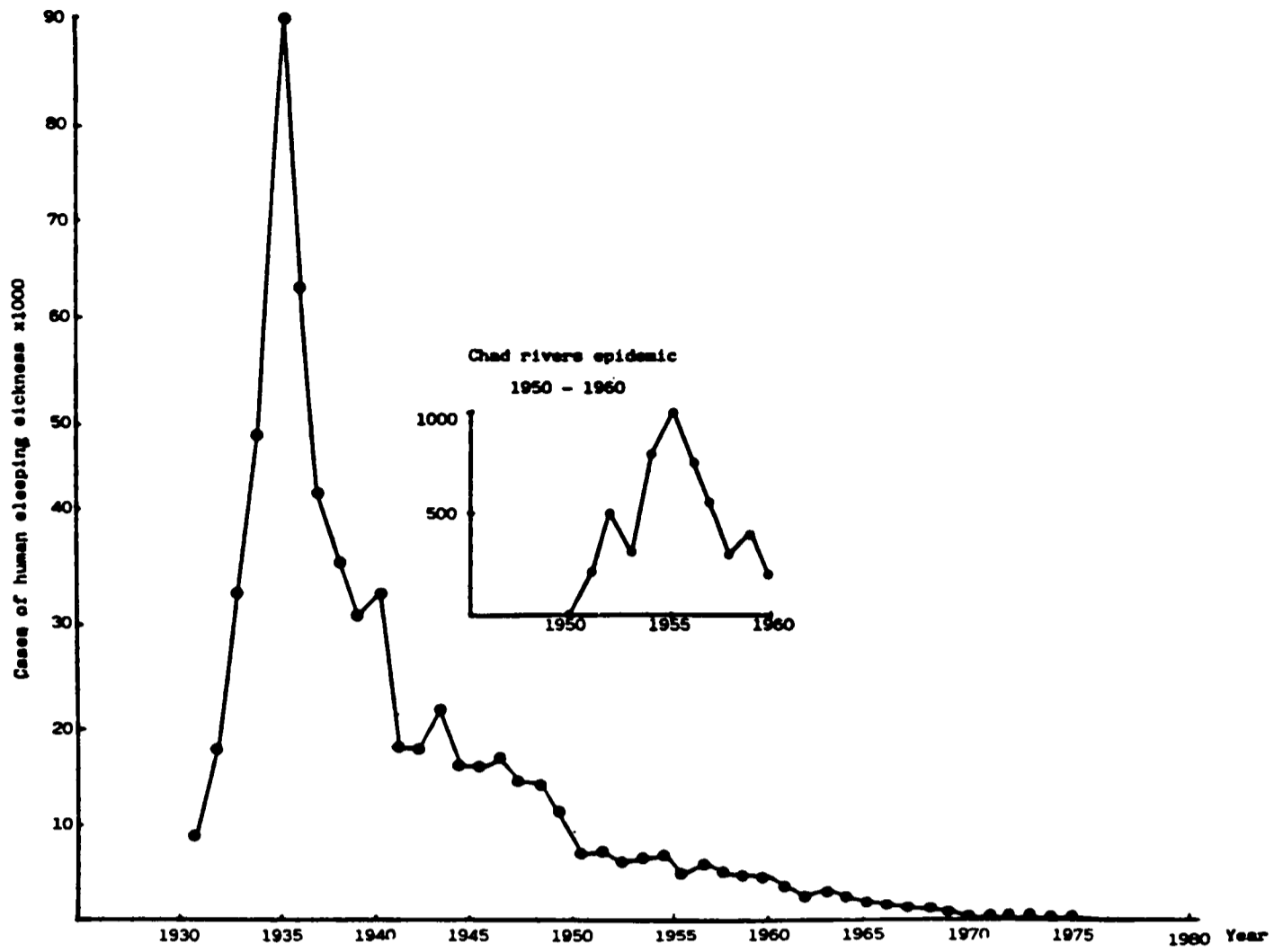


FIGURE 2.3 : CATTLE TRYPANOSOMIASIS TREATMENTS

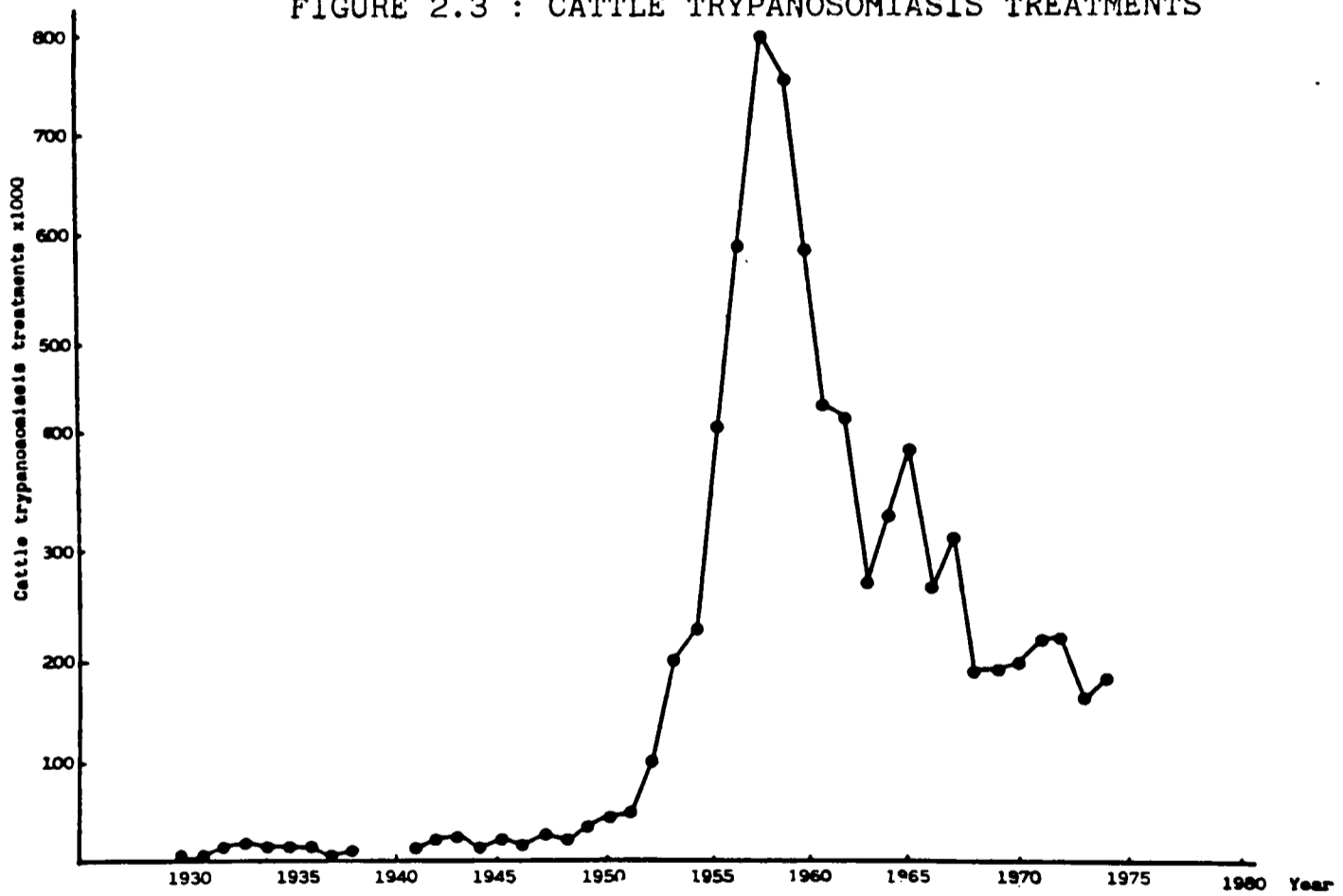
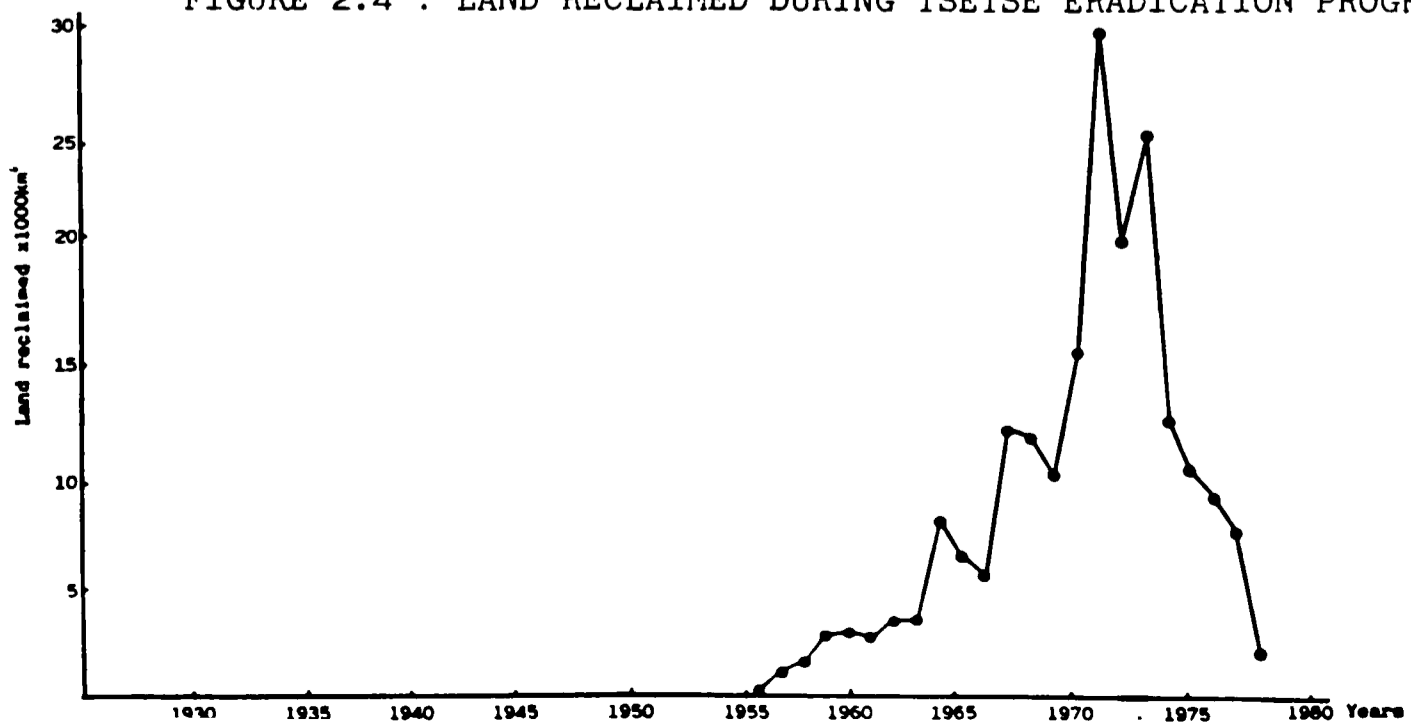


FIGURE 2.4 : LAND RECLAIMED DURING TSETSE ERADICATION PROGRAMME



As well as the massive surveillance and treatment programme described above, disease control strategy also included vector control measures. To begin with these were dependent on various forms of vegetation clearance and destruction of tsetse habitats in order to reduce man-fly contact. The Anchau Rural Development and Settlement Scheme, which was started in 1937, under the supervision of the Sleeping Sickness Service, is probably the most famous, and involved amongst other activities, the clearance of vegetation along some 1,100 kilometers of drainage line. Subsequently this scheme came to form part of a much larger operation, covering parts of Katsina, Kano and Zaria provinces - the KKZ scheme - which between 1950 and 1960 removed vegetation from more than 5,000 kilometers of streams and rivers (Glover, 1965).

A great deal of manpower was required for this kind of work, and major logistic problems were encountered with the maintenance of cleared areas in both the Anchau and KKZ schemes. Labour costs also increased appreciably, and eventually organised vegetation clearance as a method of tsetse control was largely replaced by the application of insecticide, except where it was used in conjunction with insecticide to create barriers against reinvasion.

During the Chad rivers epidemic of the 1950s the disease control strategy included the use of insecticide to control tsetse populations, as well as large scale surveillance and treatment of the human population. Tsetse control operations were carried out by ground spray teams from both the Sleeping Sickness Service and the newly created Veterinary Tsetse and Trypanosomiasis Unit.

## 2.5 Cattle Trypanosomiasis.

As in man, trypanosomiasis in cattle is a highly variable disease, ranging from mild self-curing forms; through chronic infections, where the host remains in relatively good health and condition, unless subjected to stress, when relapses are likely to occur, (and are a typical characteristic of the disease in general); to acute infections rapidly leading to death.

Unlike the disease in man however, there are four species of trypanosome responsible for the disease in cattle. Two, T. brucei and T. evansi, are considered to be of only minor importance, being of generally low incidence, with mild infections in which clinical signs are seldom manifest.

Clinically T. vivax and T. congolense are usually much more obvious, although the two cannot be distinguished without blood examination. In Nigeria T. congolense is generally regarded as being associated with the chronic form of the disease, characterised by severe wasting of the animal. Death may ensue after only a few weeks, but generally takes much longer. However, spontaneous cures may also take place.

Some forms of T. vivax are associated with the acute form of the disease, with death occurring within two weeks of trypanosomes first appearing in the blood. However, other strains have been found, in which the disease is extremely mild, showing few if any clinical signs.

Zebu cattle are generally considered to be highly susceptible to infection by T. vivax and T. congolense, whilst the trypanotolerant Muturu, N'dama and Keteku breeds appear to be more resistant to both infections, which, if they do develop, usually are of a transient nature (Stephen, 1970).

All four tsetse species commonly occurring in northern Nigeria are capable of transmitting T. vivax, T. congolense and T. brucei; but tsetse are not thought to be vectors of T. evansi.

Trypanosomiasis in cattle received relatively little attention by the Veterinary Services during the first quarter of the century. Their primary concern was vaccination against rinderpest, continuing outbreaks of which had greatly reduced the cattle population. In 1924 it was noted that trypanosomiasis was increasing, and in 1927 it was stated that trypanosomiasis was "responsible for a mortality only second in severity to that of rinderpest", and that upto 15-20% of cattle examined at rinderpest vaccination camps were infected with trypanosomes, the most commonly found being T. vivax (Nigerian Veterinary Services, 1925 and 1928). Trypanosomiasis came into prominence in 1930 when treatment by intravenous injection of tartar emetic became available. However, it was a difficult drug to administer and could have very severe side effects. Subsequent veterinary reports regularly recorded the seriousness and increasing incidence of the disease (Ford, 1971).

Ford (1971) suggested that it was not surprising that the demand for trypanosomiasis treatment increased during this and subsequent periods, as the prolonged and extensive rinderpest vaccination campaign must almost inevitably have led to an increase in the cattle population.

In the early fifties, following the general suppression of rinderpest, and its reduced pathogenicity, trypanosomiasis was described as "the greatest single impediment to livestock raising in Northern Nigeria" (Anon, 1953).

Figure 2.3 traces the course of the annual trypanosomiasis treatment figures from 1930 to the mid-seventies. In 1951 a new and far superior trypanocidal drug - Antrycide - was introduced, replacing tartar emetic, and by 1956 homidium compounds were also widely in use. Annual treatments increased dramatically during the fifties, to peak in 1957/58 at 771,438. Subsequently there was a progressive decline in treatments which fell to an annual level of around 200,000 in the late sixties and early seventies.

Numerous surveys of the incidence of trypanosomiasis in cattle have been carried out over the years, frequently based on non-random samples collected from treatment camps. Interpretation and comparison of the results has been a matter of considerable debate, both as regards their general meaning and representativeness. Reviewing the available information Putt et al. (1980) concluded that two trends were apparent. Firstly, there may well have been an increase in the incidence of trypanosomiasis in the national herd up until about 1960, but thereafter the incidence of the disease almost certainly declined. Secondly, the relative proportions of T. vivax and T. congolense infections changed, with T. vivax tending to decrease, and T. congolense to increase.

## 2.6 Tsetse Eradication.

During the period of rapid increase in trypanosomiasis treatments in the mid-fifties, the Veterinary Tsetse and Trypanosomiasis Unit, which was established in 1953, began tsetse control operations in the Chad basin using selective techniques of ground application of insecticide. The spraying proved highly effective against G. morsitans and G. tachinoides populations, which were both at the limit of their range. This work was to form the basis of the Nigerian tsetse eradication programme, which between 1955 and 1978 reclaimed some 200.000 square kilometers of land in north-eastern Nigeria (figure 2.6). Figure 2.4 shows the amount of land reclaimed annually during this period. Features of this programme are considered in more detail in Chapter 3.

## 2.7 Assessment.

The objectives of this very brief outline of some fifty years of tsetse and trypanosomiasis control in Nigeria has been to illustrate: the changing pattern of the disease itself; the generally declining importance of both human and animal trypanosomiasis; and a significant switch in control strategy.

From being a disease primarily of medical interest and importance, with control measures involving surveillance of the human population, drug treatment of sleeping sickness cases and limited vector control by vegetation clearance; the disease has, since the late forties and early fifties, become one primarily of veterinary concern, with control measures involving drug treatment and vector eradication through the application of insecticide.

FIGURE 2.5 : PRIMORDIAL SLEEPING SICKNESS ZONES  
( AFTER DUGGAN, 1962 )

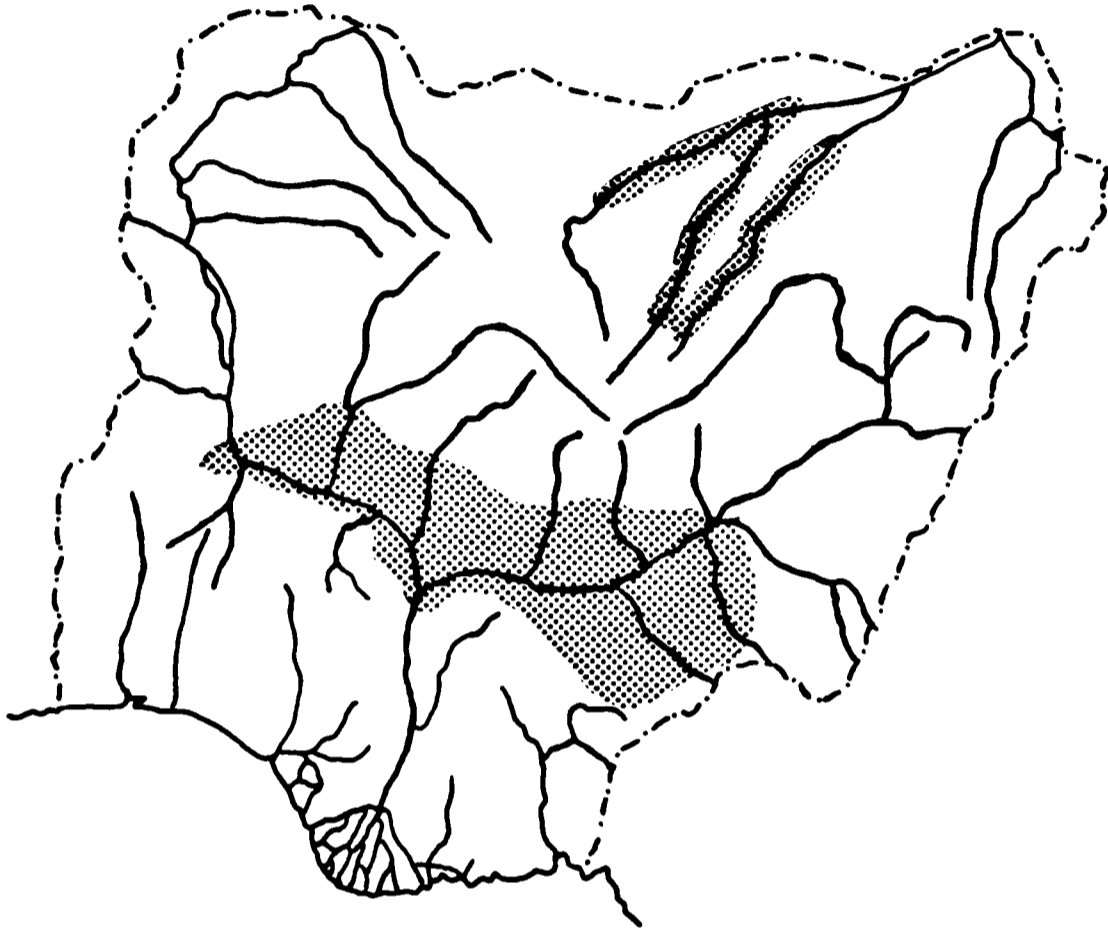
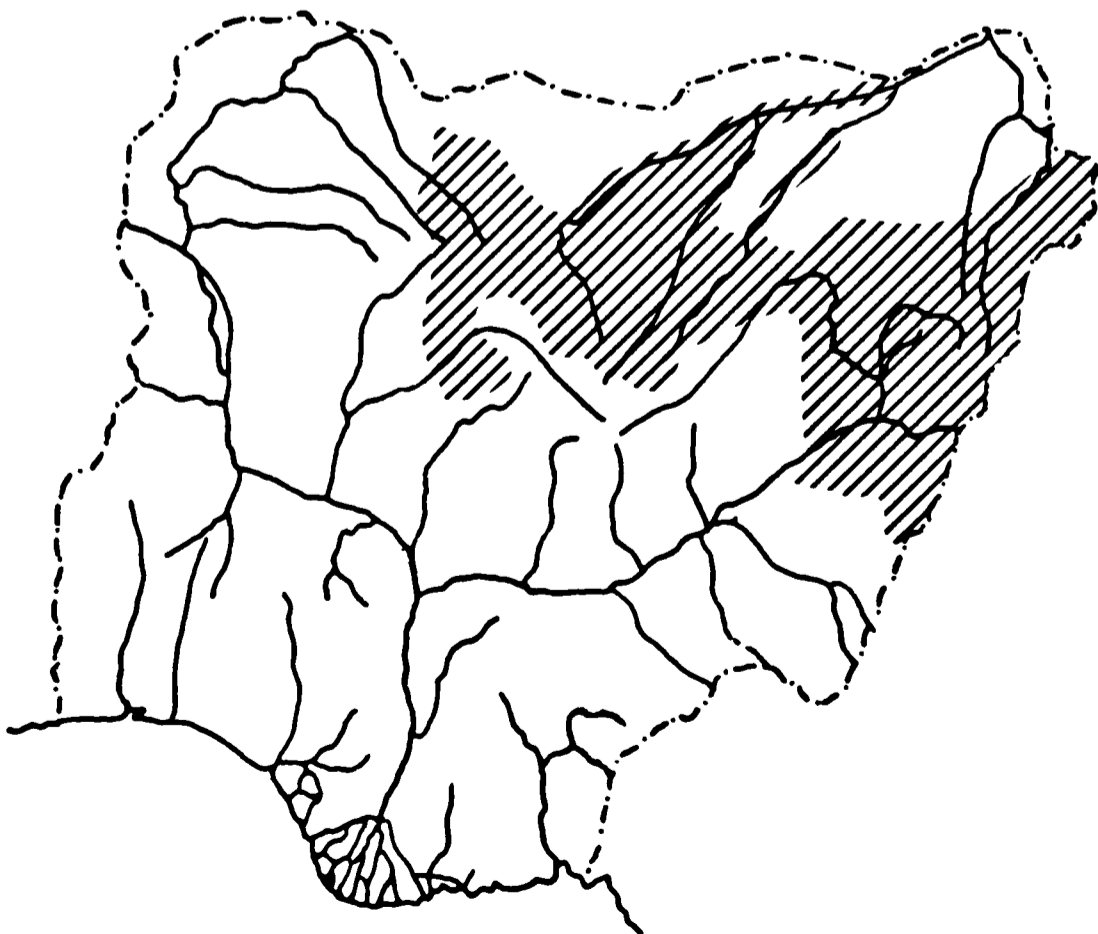


FIGURE 2.6 : TSETSE ERADICATION ZONE  
( AFTER T.T.D., 1978 )



There has been much debate over the possible causes for the rise and fall of both human and animal trypanosomiasis. While numerous factors have undoubtedly played a part and have been extensively discussed by Putt et al. (1980), and others before them, one factor in particular was considered to be of major, if not, overriding importance. That was the widespread and profound indirect effect that the activity of Nigeria's increasing and expanding human population has had on all vector populations, by modifying their habitats and altering the balance of host availability.

Whilst often given passing reference in the tsetse and trypanosomiasis literature, few studies have focused on the general effects of human activity on tsetse populations in Nigeria. To quote Ford (1971) "it is the sort of situation that is fundamental in the problem of trypanosomiasis but is neglected because it demands the exploration of fields of knowledge not within the usual purviews of entomologists or parasitologists". The following chapters represent a tentative exploration of some of those fields.

### 3 FEATURES OF THE NIGERIAN TSETSE ERADICATION PROGRAMME.

#### 3.1 Background.

Before the introduction of insecticides, government organised tsetse control measures in Nigeria relied on various forms of vegetation clearance. The first organochlorine, residual insecticides were produced on a commercial scale in the late 1930s. Pioneer work in East Africa in the late 1940s had shown that DDT and BHC were lethal to tsetse under laboratory and field conditions (Vanderplank, 1947; Symes et al., 1948). In the early 1950s the Sleeping Sickness Service Tsetse Control Unit and the Veterinary Tsetse and Trypanosomiasis Unit began experimenting with the use of insecticide, and developing techniques suitable for Nigerian conditions. Insecticide application proved highly effective against tsetse, and soon replaced vegetation clearance as the primary means of tsetse control.

In Nigeria, a distinction has been drawn between tsetse "control operations", which were intended only to reduce local tsetse population levels, or restrict their distribution on a limited scale; and "eradication projects" which were intended permanently to eliminate tsetse from much larger areas.

Tsetse control operations generally took place away from the natural limits of tsetse distribution, and were carried out as a protective measure in areas where sleeping sickness foci persisted; on stock farms and cattle ranches; on trade cattle routes; and around tourist accommodation in the Yankari game reserve.

Eradication can be regarded as an extreme form of control, in circumstances where repopulation is not possible, or is prevented. The attraction of eradication, is that it should be a once and for all activity and expense, whereas tsetse control requires a continuing commitment.

The tsetse eradication programme began in 1955 in north-eastern Nigeria, within the Chad drainage basin, at the northern limits of G. morsitans and G. tachinoides distribution. Individual tsetse eradication projects, which were initially based on river systems (e.g. Komadugu Gana, Katagum and Hadeija), were extended annually, and new projects were established in neighbouring river systems. The various projects eventually linked up and the eradication zone progressively spread southwards and westwards, away from the former limits of tsetse distribution and into areas with less extreme climates, where a third tsetse species (G. palpalis) was also encountered. (See figures 2.1 and 2.6.)

The progress of the eradication programme, and the development of the various techniques employed have been described in the annual reports of the Tsetse and Trypanosomiasis Division (TTD) 1954-1978 and numerous scientific papers: Blasdale (1960); Davies. J. (1959 and 1960); Davies. H. (1964, 1971 and 1977); Davies. H. and Blasdale (1960); Glover (1965); Kernaghan (1960 and 1961); Kernaghan and J. Davies (1959); Kirkby and Blasdale (1960); MacLennan (1964, 1966 and 1967); MacLennan and Aitchison (1963); MacLennan and Kirkby (1959); MacLennan and Na'isa (1971); Mahood (1960 and 1962); Spielberger and Abdurrahim (1971); and Spielberger et al. (1977).

During the course of the eradication programme, as experience was gained and different conditions were encountered, techniques of insecticide application were modified and new methods were introduced; various formulations and different insecticides were tested; and the system of reporting eradication statistics was altered. An attempt has been made in the following sections to standardise the available information, and draw attention to particular features of the eradication programme. First however, it is necessary briefly to describe the methods of insecticide application that were employed.

### 3.2 Insecticide Application Methods.

#### 3.2.1. Ground Spraying.

At the limits of their range, the distribution of tsetse is determined largely by climatic factors (temperature and aridity). In extreme conditions prevailing in the Sudan vegetation zone during the height of the dry season, tsetse are restricted to limited areas of riverine and thicket vegetation, which provide suitable microclimates. During and after the rains, when climatic conditions are less extreme, tsetse are no longer confined to the same extent, and dispersal takes place into surrounding areas.

The strategy adopted in ground spraying operations was to attack the tsetse in the dry season when their distribution was most limited and populations were under greatest stress. Persistent insecticides (DDT and Dieldrin) were applied "discriminatively" to riverine and thicket vegetation by teams of men with back-pack sprayers. Experience showed

that it was not necessary to spray all of the infested habitat. Insecticide was applied only around the margins and along paths cut through wider thickets and more extensive riverine vegetation; or, alternatively, where the stream bed was easily accessible and the fringing forest relatively narrow, only vegetation on the banks was treated. In addition to discriminative spraying, insecticides were "selectively" applied to specific surfaces which were considered to be suitable tsetse resting sites, e.g. on the trunks of larger trees, 0.5-1.5 meters above ground level.

With this kind of operation, involving large gangs of men working in comparative isolation and under difficult conditions, it was not possible to collect precise information on the area that had been sprayed, or the concentration of the insecticide deposited. However, records were kept of the total amount of insecticide used; the length of riverine habitat in the spraying zone; the total operational area; and estimates were made of the extent of reclaimed land, previously occupied by tsetse during the wet season, which had been freed from the risk of tsetse challenge and, in theory, therefore made available for grazing.

As well as the selective and discriminative spraying, "barriers" were created by the blanket application of insecticide to wide strips of vegetation at key points, in an attempt to prevent reinvasion of previously reclaimed areas. Where these barriers failed and reinvasions occurred, or where tsetse populations had survived the initial application of insecticide, respraying operations were subsequently carried out.

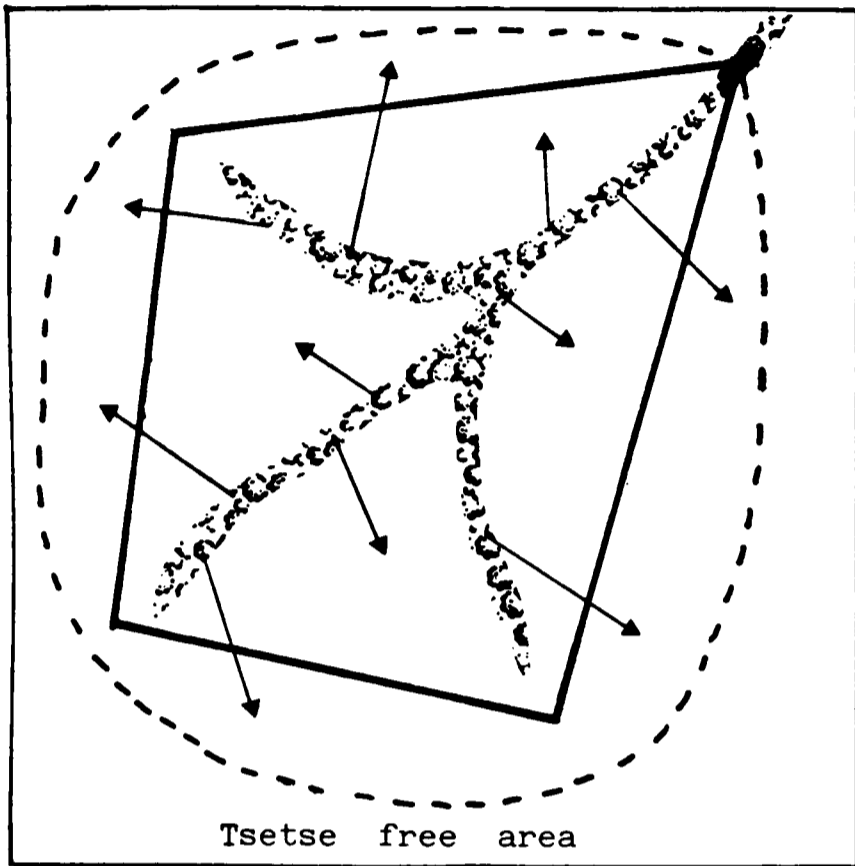
The various areas and zones are illustrated in figure 3.1 A, which represents the situation at the limits of tsetse distribution in the Sudan vegetation zone. It can be seen that the spraying zone occupied a relatively small proportion of the total reclaimed area. As the eradication programme moved southwards, away from the limits of tsetse distribution, and into the Guinea vegetation zone (figure 3.1 B), suitable tsetse habitats tended to be more extensive; the spraying zone occupied an increasing proportion of the operational area; and the extent of the operational area approached that of the land reclaimed. Under these circumstances the risks of reinvasion were higher and it was considered necessary to increase the concentration of insecticide in order to prolong the persistence of deposits.

### 3.2.2. Helicopter Spraying.

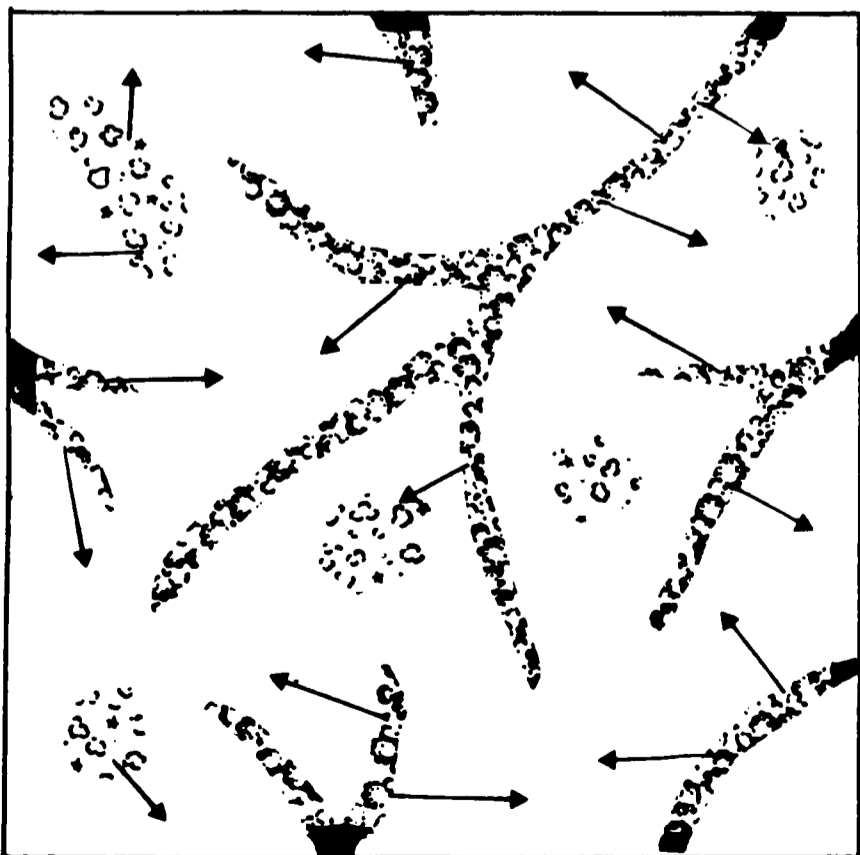
The strategy adopted by the helicopter spraying programme was essentially similar to that of ground operations. Spraying was restricted to dry season tsetse habitats, with the purpose of creating a surface deposit of persistent insecticide, upon which tsetse would subsequently settle. Selective application however, was not possible. The helicopter programme began in 1970/71 and operated in northern and southern Guinea vegetation zones, using Bell G4 280 HP helicopters. This work, and the development of the techniques employed, has been described by Spielberger et al. (1977). Rotor down-draught was utilised to propel droplets of insecticide into tsetse habitats. Initially, a conventional water/oil insecticide emulsion was sprayed, but it was found to have poor canopy penetration properties. Subsequently, an ultra low volume (ULV) spraying technique was developed, which gave better penetration. A number of insecticides of different formulations were tested, but Dieldrin, and latterly Endosulfan were the most commonly used.

FIGURE 3.1 : TSETSE ERADICATION OPERATIONS.

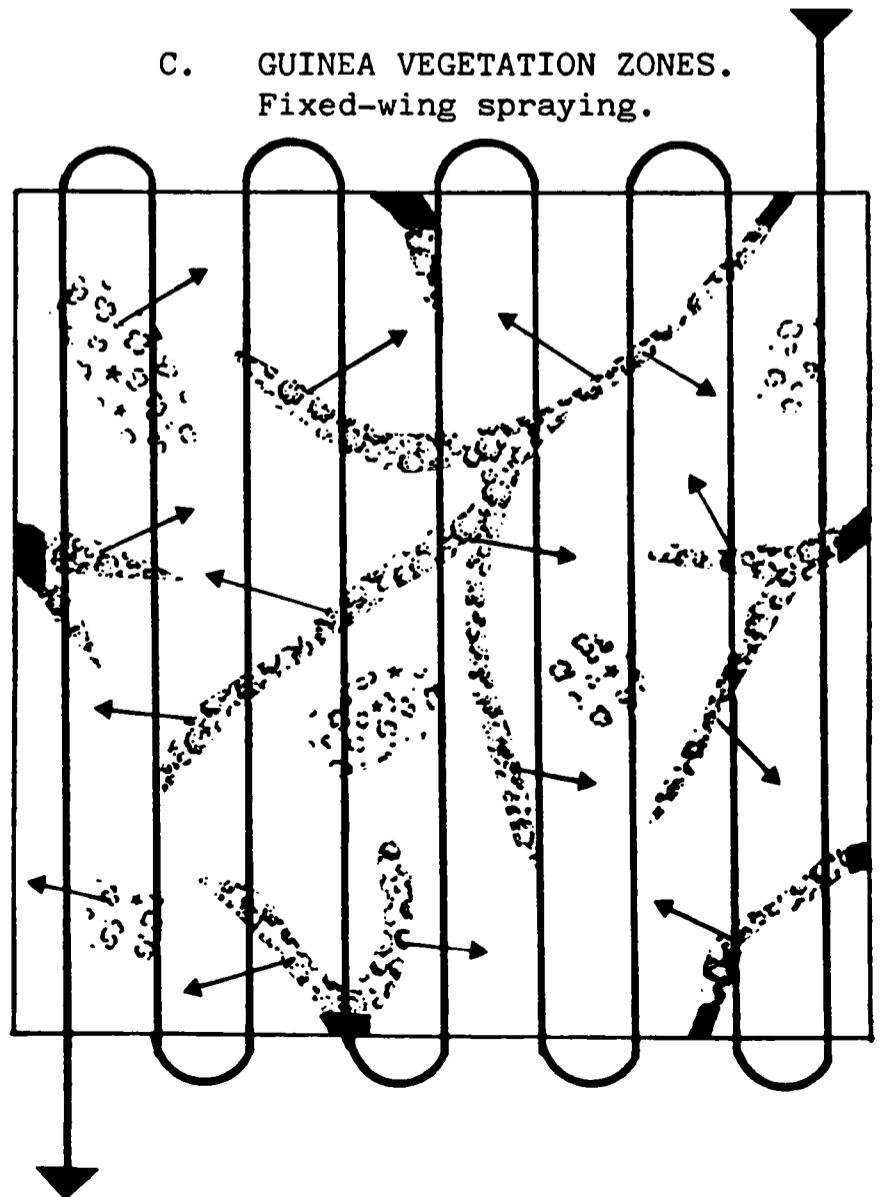
A. SUDAN VEGETATION ZONE.  
Ground spraying.



B. GUINEA VEGETATION ZONES.  
Ground and helicopter spraying.



C. GUINEA VEGETATION ZONES.  
Fixed-wing spraying.



Working in the Guinea vegetation zone, the helicopter spraying programme faced major reinvasion problems, which became increasingly severe in the southern Guinea zone. Insecticide barriers were created by ground spray teams in order to isolate operational areas, but despite this, reinvasion was a continuing feature, and extensive respraying was required.

### 3.2.3 Fixed-Wing Spraying.

Application of insecticide by fixed-wing aircraft has been carried out more recently, largely on an experimental basis. Trials, using Piper Aztec and Pilatus aircraft spraying Endosulfan, were conducted in 1975/76, 1976/77 and 1981/82. The underlying principle of insecticide application by fixed-wing aircraft is fundamentally different from that of ground and helicopter application. The whole operational area is sprayed with a ULV aerosol of non-persistent insecticide, from one or more aircraft flying at low altitude along parallel tracks (figure 3.1 C). If climatic conditions are favourable and a temperature inversion exists, the aerosol will sink and permeate tsetse habitats, and drift around to make direct and lethal contact with active tsetse. This "knock-down" effect takes place for only a relatively short period. Fixed-wing insecticide applications must therefore be repeated in a series of spray cycles (up to 5 or 6), timed to strike tsetse that have emerged since the previous application, before their first larviposition.

### 3.3 Land Reclaimed.

Between 1955 and 1978 the Nigerian tsetse eradication programme reclaimed a total of some 200,000 square kilometers of land from tsetse. Approximately half of this was achieved during the peak reclamation period from 1969 to 1974. Figure 3.2 illustrates this and indicates the area of land reclaimed by the three methods of insecticide application. See table 3.1 for an overall summary of eradication statistics.

Ground spraying was carried out every year and accounted for 93% of the total eradication zone. Helicopter spraying took place from 1970 to 1978 and accounted for 6% of the land area reclaimed. Fixed-wing spraying was experimental and accounted for only 1%.

### 3.4 Insecticide Usage.

Figure 3.3 indicates the increasing amount of insecticide used annually during the eradication programme. A total of 823 tonnes of insecticide active ingredient were sprayed: 570 tonnes of DDT; 176 tonnes of Dieldrin and 77 tonnes of Endosulfan.

Ground spraying operations accounted for all of the DDT applied and some of the Dieldrin. Helicopter operations, which commenced in 1970/71, accounted for the increasing use of Dieldrin during the 1970s, and for much of the Endosulfan which was sprayed from 1973/74 onwards. Endosulfan was also applied by fixed-wing aircraft in 1976/77.

FIGURE 3.2 : LAND RECLAIMED

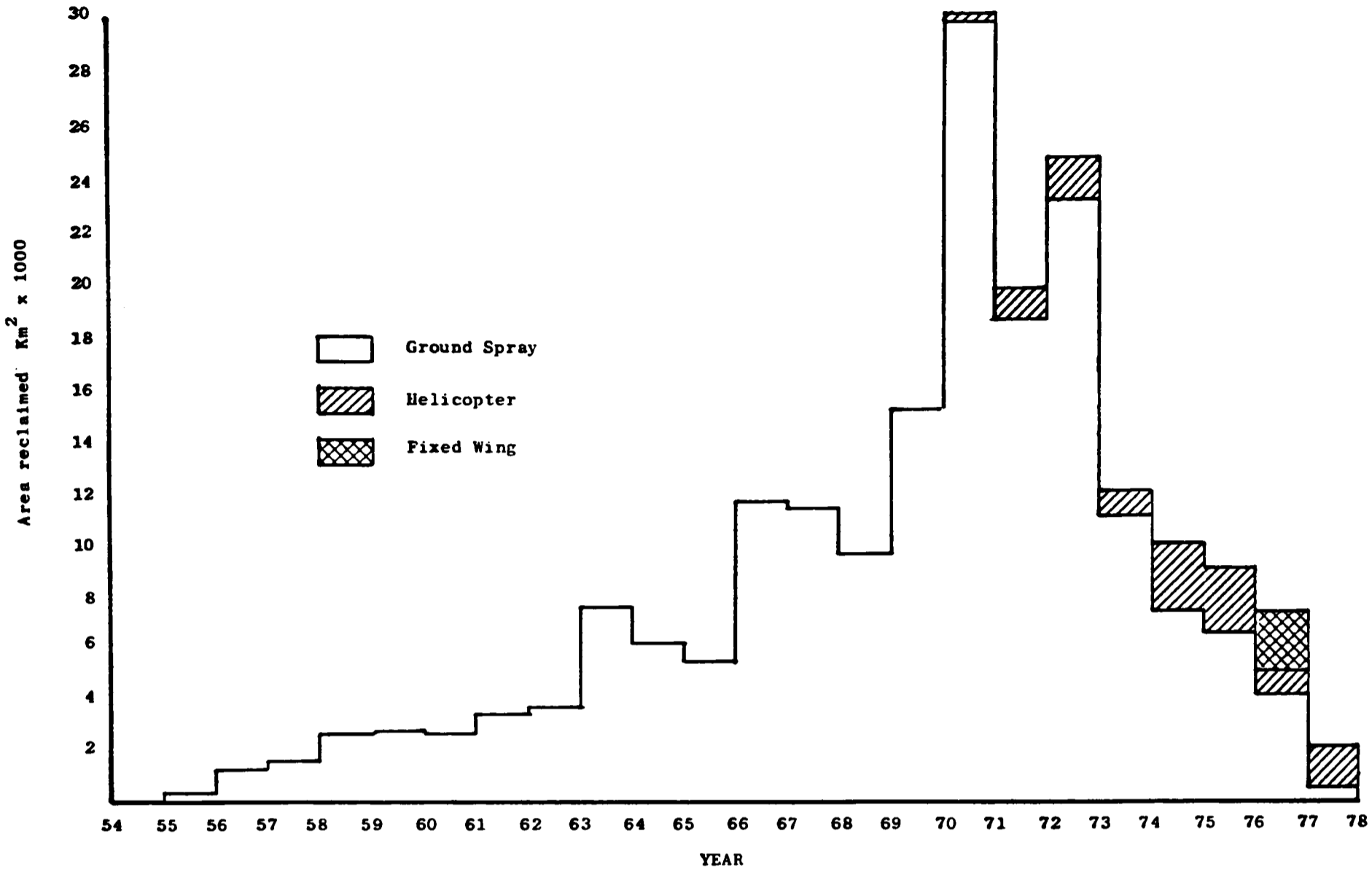


FIGURE 3.3 : INSECTICIDE USAGE

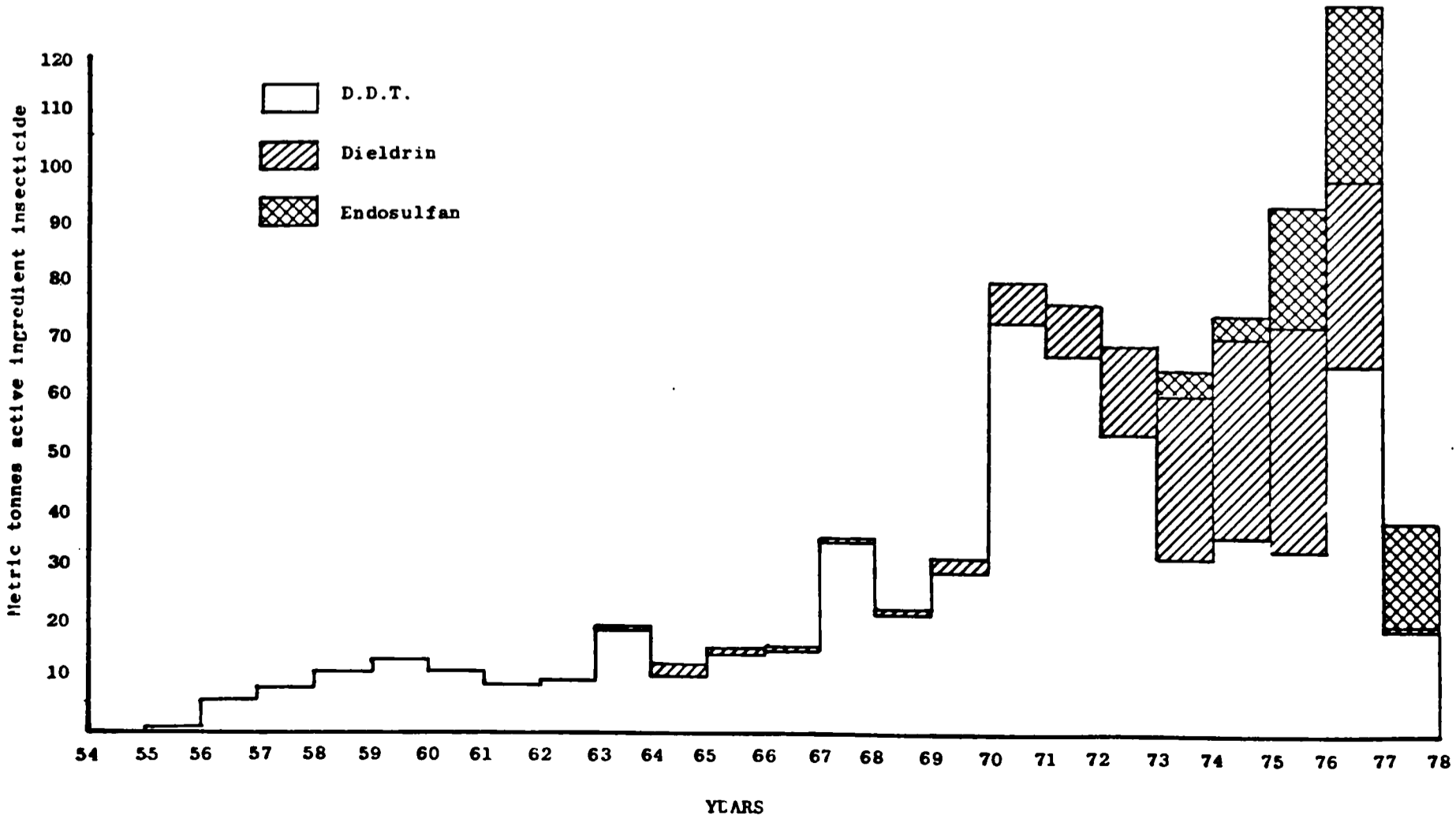
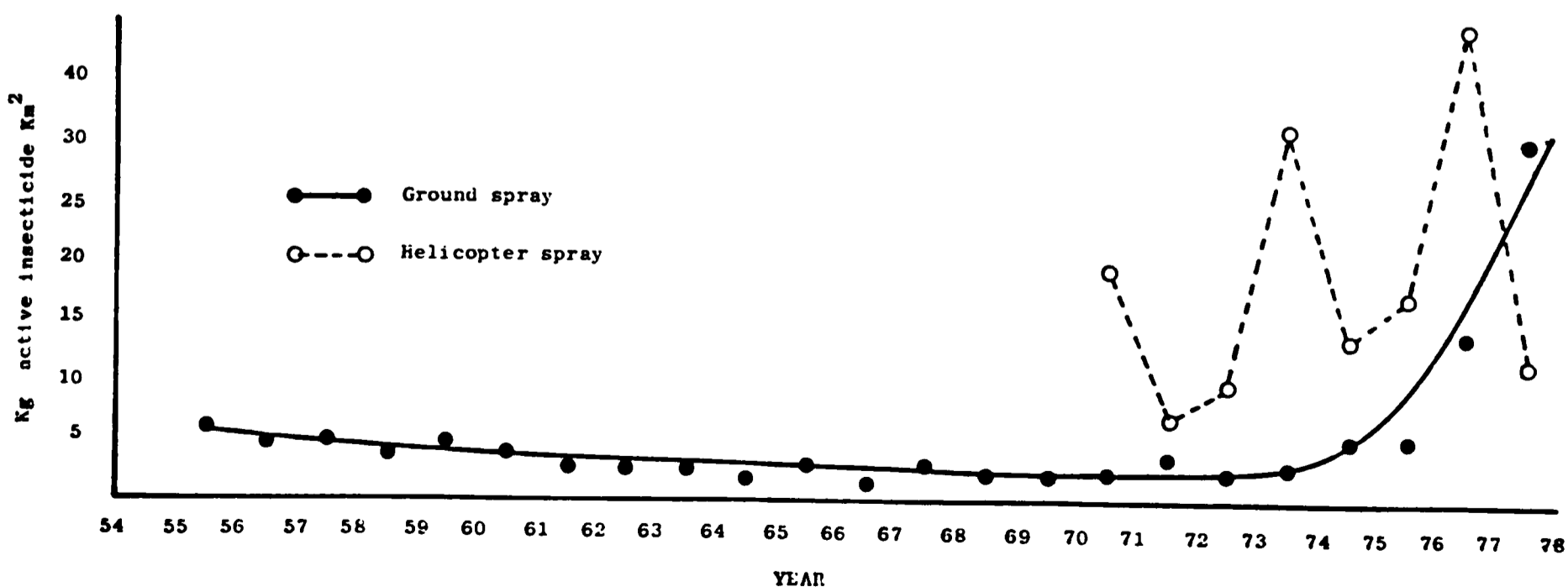


TABLE 3.1 SUMMARY OF NIGERIAN TSETSE ERADICATION PROGRAMME STATISTICS.

	Method of Insecticide Application			Total
	Ground	Helicopter	Fixed-Wing	
Time period	1954-1978	1970-1978	1975-1977	1954-1978
	square kilometers			
Land Reclaimed	184,495	11,906	2,240	198,641
Operational Area				
New spray	104,695	11,906	4,240	120,841
Respray	24,329	7,205	-	31,534
Additional Land	79,800	-	-	79,800
	kilograms active ingredient			
Isecticide Usage				
DDT	569,825	-	-	569,825
Dieldrin	17,203	159,281	-	176,484
Endosulfan	-	42,704	34,790	77,494
Total	589,028	201,985	34,790	823,803

FIGURE 3.4 : INSECTICIDE PER SQUARE KILOMETER OF LAND RECLAIMED



Surprisingly, the peak years of insecticide usage, 1975 to 1977, did not correspond with the peak years of land reclamation, 1969 to 1974. The amount of insecticide used per square kilometer of land reclaimed is shown in figure 3.4. Over the twenty year period from 1955 to 1974 the level for ground spraying operations gradually declined from around 5 kg. a.i. per square kilometer, to about 2.5 kg. a.i. per square kilometer. More recently, this trend has been dramatically reversed, and the level rose to 30.0 kg. a.i. per square kilometer in 1977/78. This exceptionally high level, representing a ten-fold increase, was principally due to the increasing amount of respraying required; the more extensive tsetse habitats that were encountered; and the higher concentrations of insecticide that were applied.

Helicopter spraying rates are also shown in figure 3.4. They were generally higher than for ground spraying, but fluctuated considerably from year to year (7.5 - 50 kg. a.i. per square kilometer), depending on the extent of respraying. For comparison, fixed-wing insecticide application rates in the trials carried out in 1975/76 and 1976/77 were 7.9 and 8.5 kg. a.i. per square kilometer.

### 3.5 Operational Areas.

The reappearance of tsetse in areas that had previously been sprayed was not an infrequent occurrence, and can be attributed, either to the survival of tsetse populations within the area, or to reinvasion from neighbouring regions. The year's spraying operations therefore usually included some new spraying, and some respraying. See figures 3.5 and 3.6 for ground and helicopter operations respectively.

FIGURE 3.5 : OPERATIONAL AREA - GROUND SPRAYING

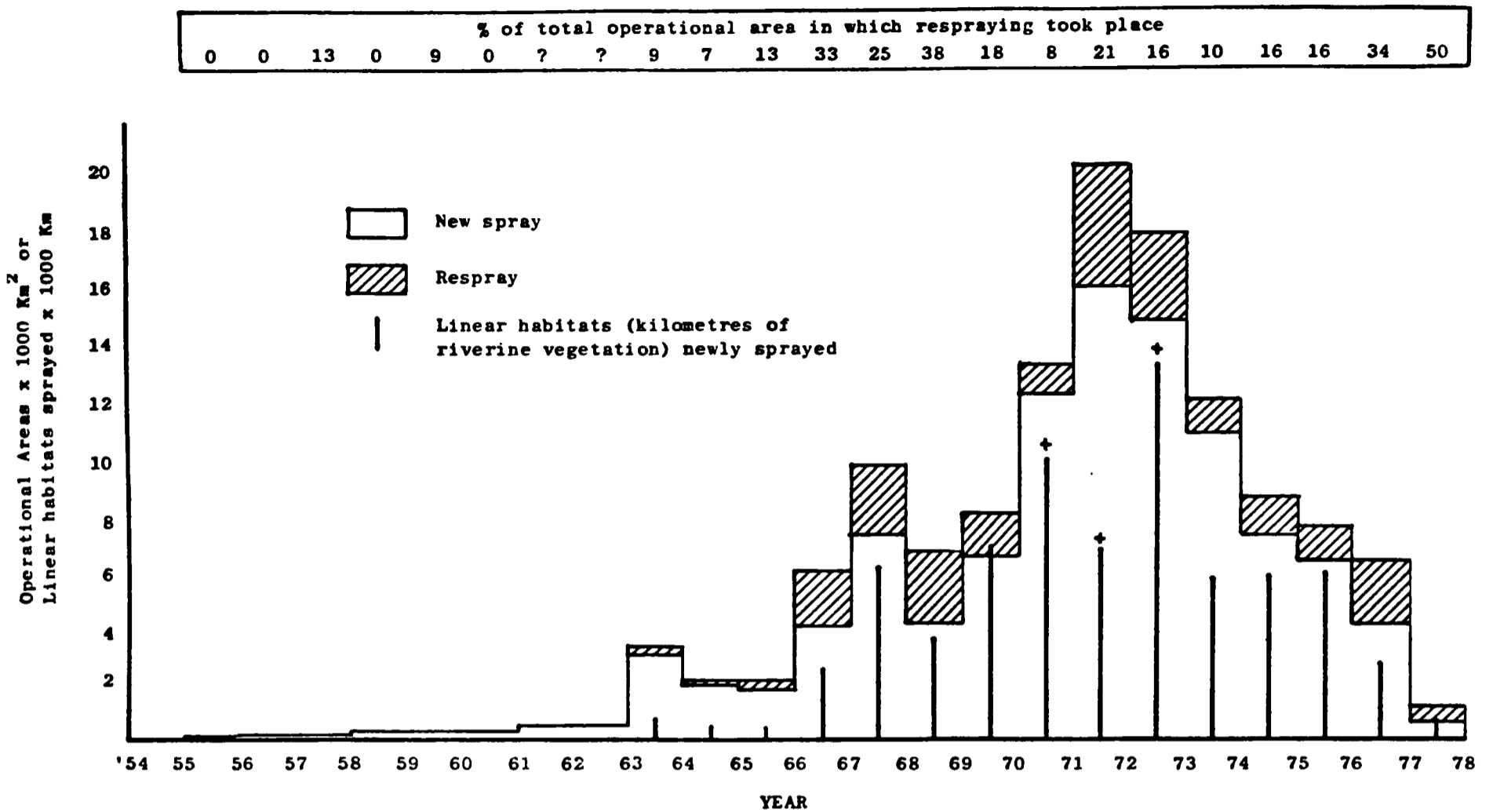
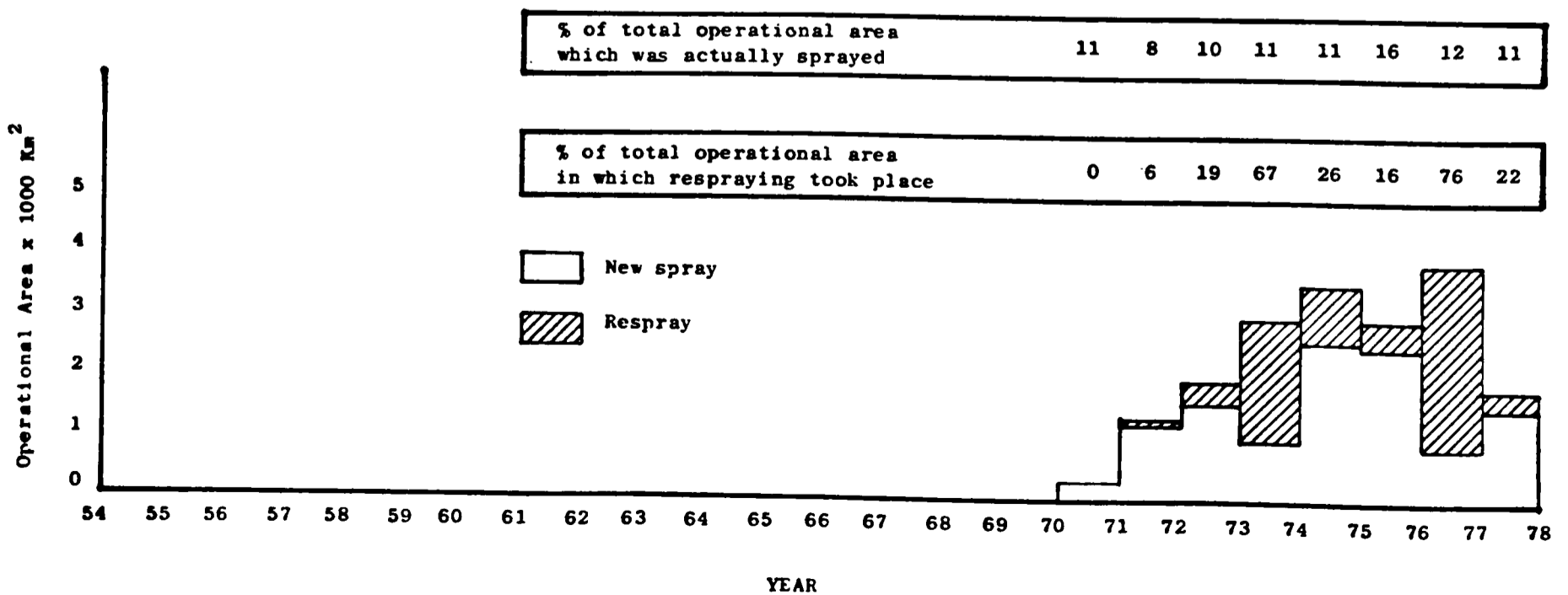


FIGURE 3.6 : OPERATIONAL AREA - HELICOPTER SPRAYING



The proportion of respraying required varied considerably from year to year, but tended to increase as the eradication programme expanded southwards and entered regions with less severe climatic conditions and more widespread tsetse habitats. This was particularly true for the helicopter programme, working in the Guinea vegetation zone.

It is important to stress that only a small proportion of the operational area was physically sprayed. Both helicopter and ground spraying involved a high degree of discrimination and only tsetse habitats were treated - mostly riverine forest and thicket vegetation. The helicopter spray zone occupied from 8% to 16% of the operational area.

The ground teams practised selective spraying of particular sites, as well as discriminative spraying, and thus the extent of the area actually sprayed could not be reliably determined. However, as an indication of the intensity of ground spraying, the lengths of linear habitat (riverine vegetation) treated each year are shown as thick vertical lines in figure 3.5. Usually less than one kilometer of linear habitat was treated for each square kilometer of operational area. However, it should be remembered that some spraying of upland vegetation also took place.

### 3.6 Additonal Land.

As previously explained, the land reclaimed each year included not only that year's operational area, but also "additional" land outside the operational area, which had been freed from the risk of tsetse challenge as a result of neighbouring spraying.

Figure 3.7 shows the additional land which was included in the area reclaimed each year until 1973, when the method of reporting eradication statistics was changed, and the additional land category was dropped. Over the period 1955 to 1973 the total area of additional land amounted to some 80,000 square kilometers, more than half of the land that had by then been reclaimed.

### 3.7 Efficiency of Reclamation.

A measure of efficiency of the Nigerian tsetse eradication programme may be obtained from the land reclaimed per employee. It was not possible to determine the total number of casual labourers working on the various spraying operations each year. However, records were available for permanent junior and senior staff employed on eradication duties by TTD.

Figure 3.8 represents a crude measure of the changes that have occurred in the relative efficiency of the eradication programme in terms of the number of square kilometers reclaimed per permanent member of staff each year. It can be seen that efficiency gradually increased from a late 1950s value of about 25 square kilometers per man per year, to reach a peak in 1970/71 of 117 square kilometers per man per year. Subsequently efficiency declined to about seven square kilometers per man per year in 1977/78.

FIGURE 3.7 : ADDITIONAL LAND

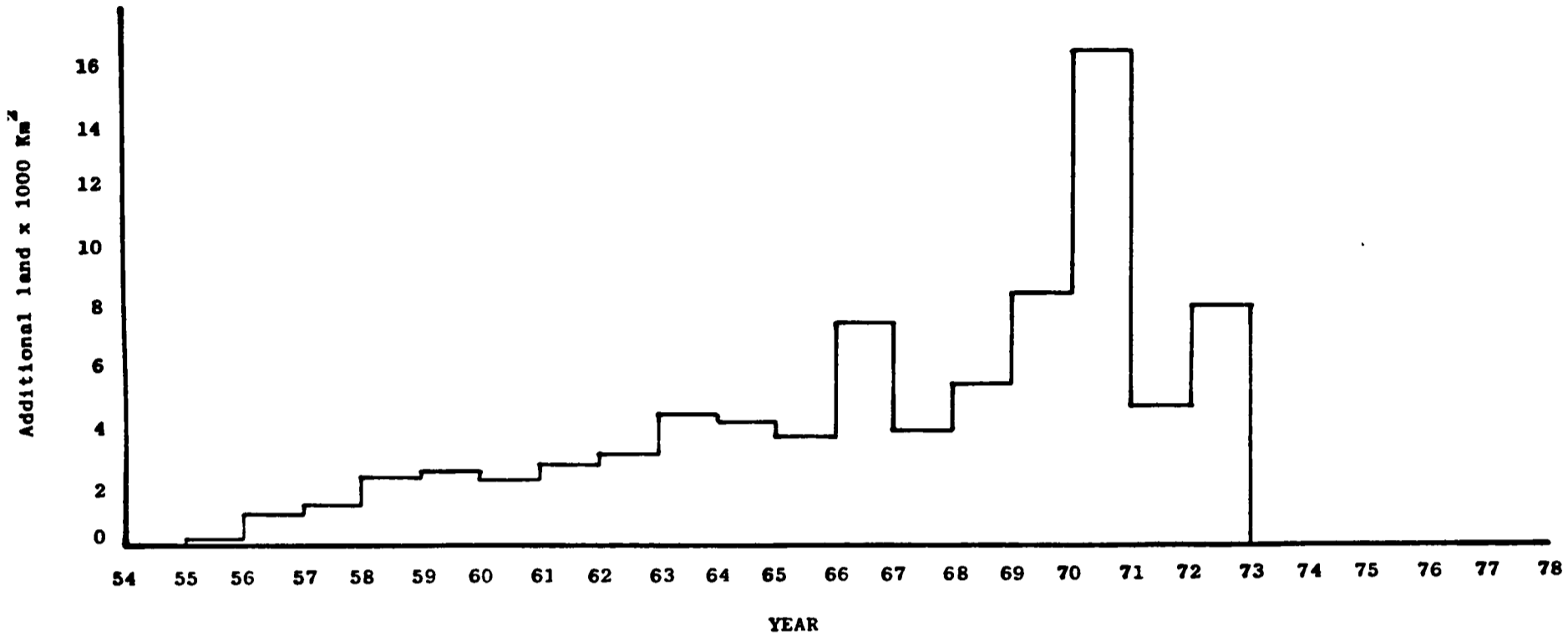
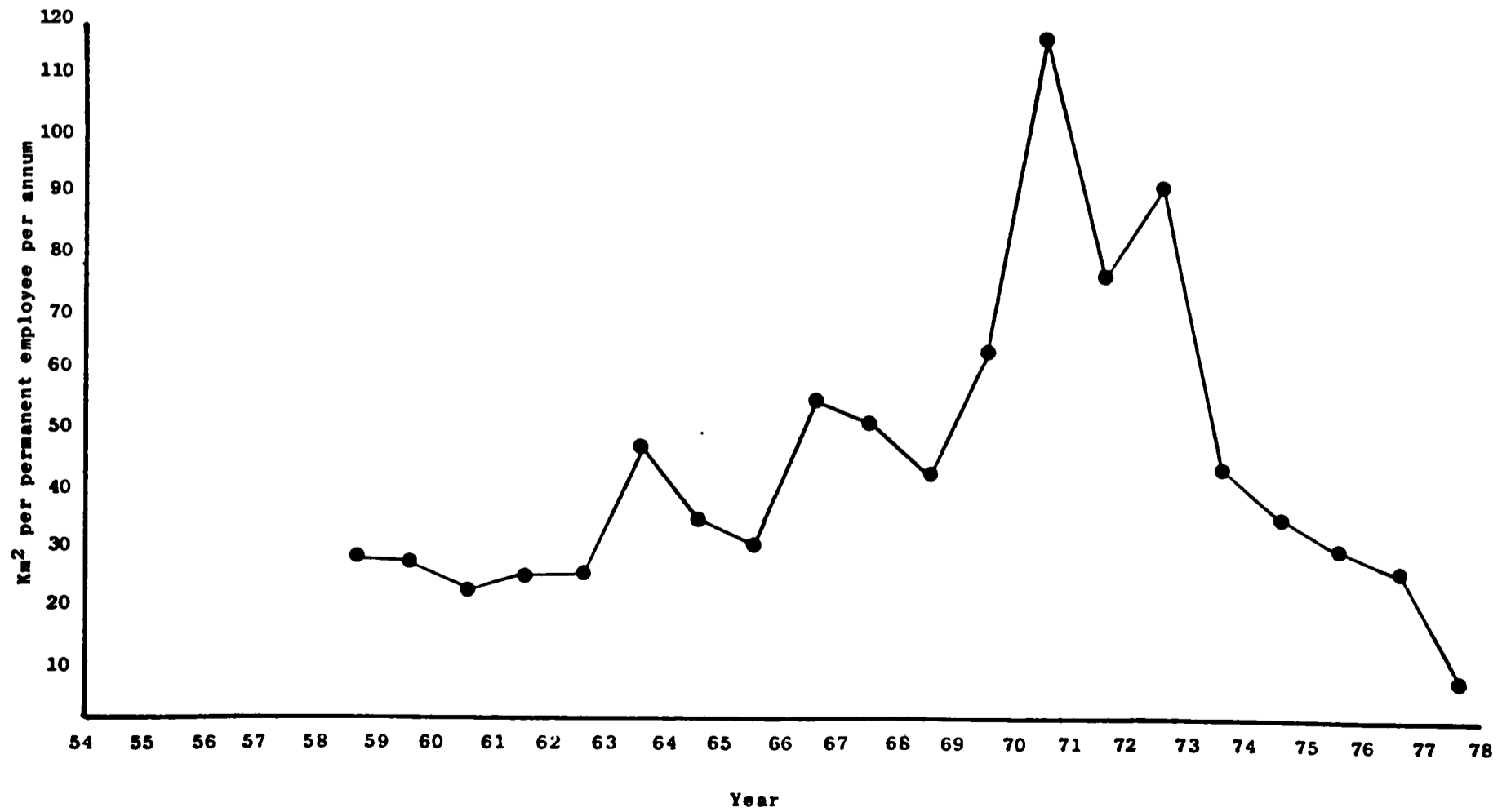


FIGURE 3.8 : EFFICIENCY OF RECLAMATION



### 3.8 Environmental Impact of Tsetse Eradication.

Koeman and Takken (1978) have reviewed the available information on the environmental impact of tsetse control operations in Africa, including Nigeria. Their review specifically excludes "secondary impact on the environment which may result from invasion of man and cattle in areas reclaimed from tsetse". Published environmental impact studies in Nigeria have focused on the "primary" side effects of insecticide application; DDT ground spraying in Koeman and Pennings (1970); Dieldrin ground spraying in Koeman et al. (1971); Dieldrin and Endosulfan helicopter spraying in Koeman et al. (1978) and Endosulfan sprayed from fixed-wing aircraft in Takken et al. (1976).

In general terms they concluded that both aerial and ground applications of insecticide caused appreciable mortalities in many of the non-target species that were monitored - both invertebrates and vertebrates. With the exception of some insectivorous birds, most non-target populations were found to recover to pre-spraying levels within a year or so of insecticide application. However, Koeman and Takken (1978) pointed out that in reality the impact of insecticide applications was likely to be far greater than their results indicated, because relatively few non-target species were actually monitored.

### 3.9 Assessment.

During the course of the tsetse eradication programme, from 1955 to 1978, some 200,000 square kilometers of north-eastern Nigeria were freed from tsetse infestation, and the risk of tsetse challenge. The peak period of reclamation was between 1969 to 1974, when approximately half of the total area was reclaimed.

96% of the reclamation was accomplished by ground spraying operations, using DDT and Dieldrin. The remainder was carried out during the 1970s by aerial spraying, mainly from helicopters applying Dieldrin and latterly Endosulfan. Some 824 tonnes of insecticide active ingredient were used, at an overall rate of application of 4.1 kg. a.i. per square kilometer of land reclaimed. However, a high degree of discrimination was practised in the zones actually sprayed, and insecticide was only applied to specific tsetse habitats, which occupied a very small proportion of the operational area.

As the eradication programme moved southwards, away from the northern limits of tsetse distribution, climatic conditions became less extreme and tsetse habitats more widespread. Over the years a greater proportion of the operational area therefore had to be sprayed. In addition, an increasing amount of respraying was required each year to eliminate tsetse which had reinvaded and/or survived earlier spraying. During the seventies the amount of insecticide used increased from 2.5 to 30.0 kg. a.i. per square kilometer of land reclaimed.

In terms of the area of land reclaimed per permanent member of staff employed, efficiency peaked at 117 square kilometers per man in 1970/71. Subsequently there was a marked decline in efficiency of the eradication programme, and an all time low of 7 square kilometers per man per year was reached in 1977/78.

Under the extreme climatic conditions prevailing in northern Nigeria tsetse distribution was very restricted. Substantial areas of "additional" land, outside operational areas, were included in eradication statistics. Up until 1973 this amounted to some 50% of the total land reclaimed. The additional land was considered to have been freed from tsetse infestation and made safe for grazing as a result of neighbouring spraying, but according to the sixteenth Annual Report of the Tsetse and Trypanosomiasis Division, 1970 - 1973 (sic), the additional land category also included land "proven to be free of tsetse infestation by the time the operations commenced." Presumably this latter category was considered to have been infested with tsetse at one time, but it is highly debatable whether it is a legitimate inclusion in statistics purporting to show the results of the eradication programme mounted by TTD. It would seem to acknowledge that at least in certain areas, tsetse were becoming extinct before they could be eradicated. Davies (1971) has commented that "a feature of tsetse distribution over much of the area has been the gradual disappearance of G. morsitans prior to spraying" and he associated this with hunting and the decline of wildlife.

#### 4 CHANGES IN NIGERIAN TSETSE DISTRIBUTION.

This chapter summarises documented changes in tsetse distribution other than those resulting from organised tsetse control and eradication schemes, and considers some of the major influencing factors.

##### 4.1 Tsetse Distribution Maps.

Pioneer tsetse surveys in Nigeria were carried out by Dudgeon (1906), Mosier (1912), Pollard (1912), Simpson (1912 a & b) and Macfie (1913), and the first tsetse distribution map of the country was compiled by Johnson and Lloyd (1923). Over the next 25 years, during the period of major sleeping sickness epidemics, much more comprehensive information became available and Nash (1948) produced new maps of Nigerian tsetse distribution.

Since 1954, national maps of tsetse distribution, also indicating the extent of the eradication zone, have been published in the annual reports of TTD (1954 to 1978). Distribution maps have also been included in the reviews of tsetse ecology and control by Glover (1965) and Davies (1977).

The distribution patterns of Nigeria's tsetse species were first put into continental perspective in maps produced by Potts (1953/54). Subsequently, based on further information which was available some twenty years later, revised maps of continental distribution of Glossina were published by Ford and Katondo (1977). These formed the basis for the maps included in FAO's tsetse training manual (Pollock, 1982).

Tsetse distribution maps such as those mentioned above need to be treated with caution because, even though they are likely to be based on what at the time is considered to be the best available information, they tend to give a spurious sense of reality and permanence. There are a variety of reasons for this. The areas involved are frequently immense, and accessibility difficult, while manpower and financial resources are usually limited; and considerable skill, time and energy are required to catch tsetse. National tsetse distribution maps are therefore usually derived from an accumulation of tsetse survey information and spot records of positively identified specimens, which have often been collected over many years. From these accumulated records, experience of ecological requirements of a given species, and a knowledge of the local conditions, boundaries are delineated to indicate the probable limits of occurrence.

Current tsetse distribution maps of Nigeria, apart from showing the eradication zone, indicate the distribution of G. palpalis and G. tachinoides only by demarcating northern and southern limits of occurrence. The presence of G. morsitans is represented by clumps of spot location symbols, ringed to form a series of irregular, isolated "belts", with "known" or "conjectural boundaries", scattered across the mid-latitudes of Nigeria. The occurrence of other tsetse species, found in the south of the country, is indicated by spot location symbols only.

The indication of the presence of a given species within a given area is by no means indicative of continuous distribution, neither will its abundance be uniform. Thus Nigeria's published tsetse distribution maps give only a very general indication of regions within which a given species may be found.

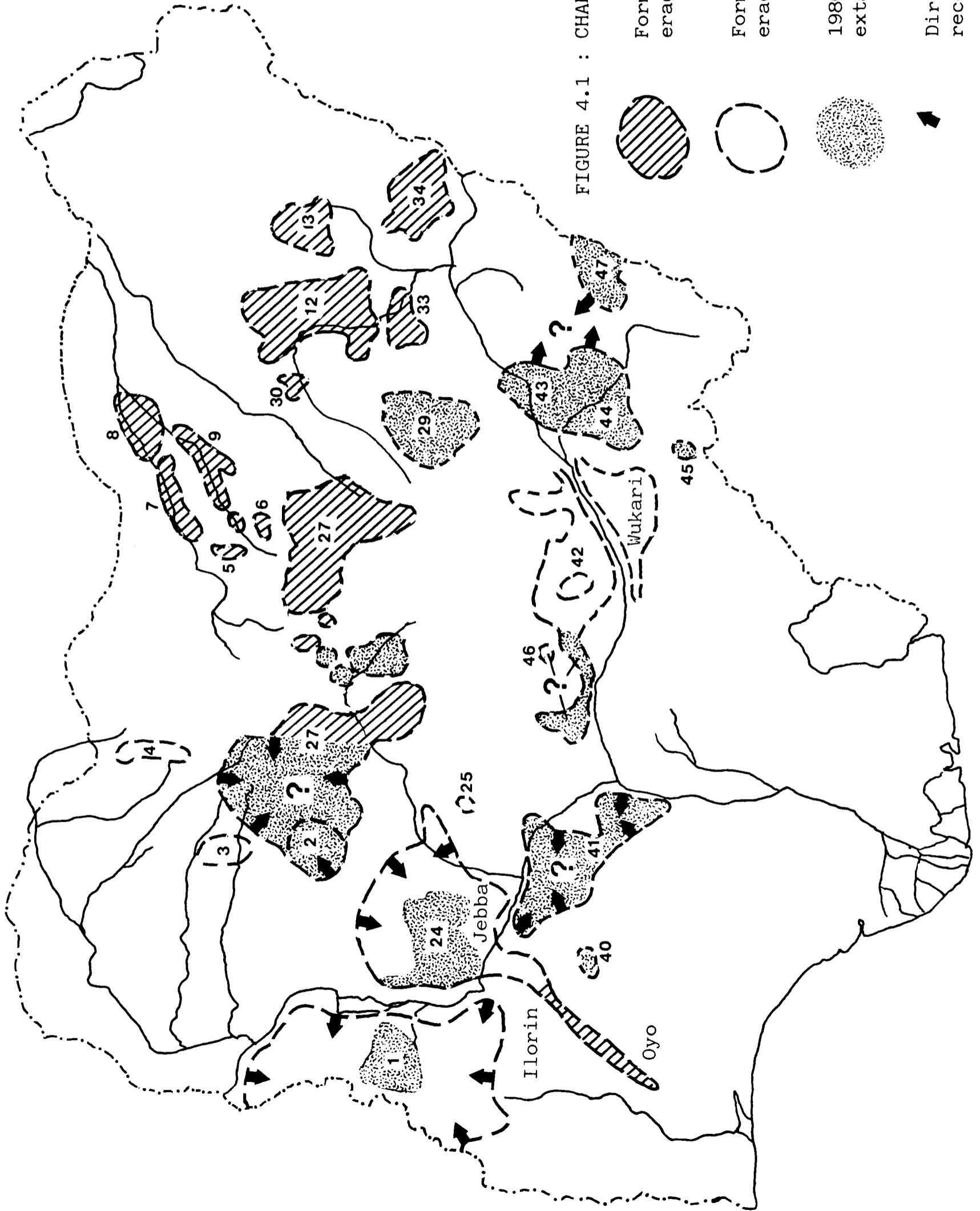
In particular areas of interest, usually of relatively small size in comparison with the country as a whole, resurveys have been, and continue to be, carried out, but the revision of national tsetse distribution boundaries takes many years. Inevitably therefore the information presented on national and continental maps is frequently out of date. Therefore, rather than consider the national picture, it is necessary to examine events at the local level.

#### 4.2 Changes in *G. morsitans* Distribution.

It has long been recognised that the fragmentary nature of *G. morsitans* belts (see figure 4.1) is a direct result of prolonged human activity in and around settled, cultivated regions, which has eliminated the natural hosts and habitats of the species, so that large areas which would otherwise be suitable are no longer capable of supporting it.

Nash (1948) drew attention to the association of *G. morsitans* belts with areas of low human population density, and stated that "*G. morsitans* occurs in areas with (human) population densities ranging from 0 to 40 per square mile; occasionally flies of this species are found in areas of 40 - 100; but never when populations exceed 100 to the square mile". He considered that major advances were unlikely to occur in Nigeria but referred to two cases; one of which appeared to have taken place north of the Benue in the period between surveys conducted by Pollard (1912) and Johnson (1918); and the other which he himself had witnessed north east of Kaduna, between 1933 and 1944. This latter advance subsequently proved to be part of the much greater advance of belt 27 mentioned again later.

FIGURE 4.1 : CHANGES IN G. MORSITANS BELTS.



Former limits within tsetse eradication zone.

Former limits outside tsetse eradication zone.

1980 conjectural limits of extant belts.

Direction of advance or recession

MacLennan (1955) in describing a tsetse survey in Wukari division of Benue province carried out in 1954, commented that in 1918 the area had been infested with G. morsitans, but that extensive farming by the local Tiv people had changed the savanna woodland to parkland, and driven out the game. As a result, G. morsitans was no longer to be found there, and the Fulani settlers who had come to the area three years previously, in 1951, when the absence of G. morsitans was first suspected, "had done extremely well".

MacLennan (1958) referred in passing to the disappearance of belt 3 (southern Sokoto province) and the Wukari fly belt. He also noted a regression that had taken place on the northern limits of belt 2, but stated that there had been considerable expansion of belt 34 (Song area of Adamawa province) and the northern and eastern boundaries of belt 27 (Anchau and Shika areas of Zaria province, respectively). He suggested that the factors influencing these changes included alterations in the pattern of human population distribution and resultant changes in vegetation; long-term climatic changes; and the movements of nomadic and trade cattle.

Wilson (1958) described in more detail the northward expansion of belt 34, and the northward and eastward expansions of belt 27, referred to by MacLennan; and also a northward expansion of belt 24 near Kontogora, Niger province. He concluded that the factors that "influenced these advances are difficult to determine, but movements in human population, climatic factors and easily available food supply provided by cattle herds grazing permanently near fly belts have all played a part. Game have exercised a very minor role."

Glover (1965) summarised the accounts of MacLennan and Wilson mentioned above, and provided the additional information that by 1958 belt 4, on the boundary between Sokoto and Katsina provinces, had ceased to exist; and that a survey of belt 43 had failed to locate any G. morsitans within its original limits, but that a few new foci had been found further south. He commented that many of the so called advances "could be attributed to imperfect previous knowledge of the areas concerned, lack of sufficiently careful and repeated surveys to detect the fly when it existed in small numbers and imperfect understanding of the ecology of G. morsitans in the Guinea zones". He went on to suggest that "as many of the recorded G. morsitans belts have not been surveyed for a number of years, other recessions may well have taken place".

Jordan (1965a) summarised catches of G. morsitans obtained from a fly-round carried out every two weeks over a five year period from 1959 to 1964, in an area 30 miles to the west of Kaduna within belt 27. The catch varied seasonally, but throughout the period G. morsitans were readily available. Two years later, when Ford (1971) visited the area he had difficulty in obtaining specimens. He noted local settlement and cultivation, and surmised that wildlife had been depleted. Jordan (1979) doubted whether any G. morsitans existed within 100 miles of Kaduna.

Glover and Aitchison (1966) mentioned a major reduction in the extent of belt 13 to the north-west of Biu, and that surveys of belt 30. south west of Fika, indicated that it had "receded and perhaps even disappeared".

Glover and Aitchison (1970) in considering the possible causes for the local decline and redistribution of human population, that had evidently occurred during the previous hundred years in many areas within the general region occupied by G. morsitans belt 27, concluded that soil exhaustion, slave raiding, Pax Britannica and the incidence of three major diseases (human trypanosomiasis, onchocerciasis and cerebral meningitis) had all been of some influence.

Ford (1971), in a review of the available information, discussed at some length the complex of interacting factors tending to limit, or cause, the expansion of G. morsitans belts. He agreed with the widely accepted view that human activity in the form of hunting, which removed suitable hosts, and cultivation, which removed suitable habitats, led to the decline and eventual disappearance of G. morsitans. He also accepted that if people moved away from an area, and natural vegetation and wildlife returned, then any remnant, or neighbouring G. morsitans populations were likely to expand within, or into the area.

Ford's interpretation of events differed from the conventional view in that he ascribed many of the reported advances of G. morsitans belts to a shift in the host-vector balance brought about by government activity. Namely, through the introduction of, and massive treatments with, new trypanocidal drugs (first Antrycide, and later Homidium) in the early fifties. These "enabled cattle to remain in areas from which, before 1950, they would have been forced to retreat"; and had the highly desirable side effect of "a marked reduction in the number

of abortions". According to Ford, the inevitable result of this was that "in the space of a few years a vast new supply of blood in highly acceptable host animals was made available", which in turn led to the observed widespread expansion of G. morsitans belts in the late fifties and sixties. As one might expect, these views were highly controversial.

Ford suggested that the southward expansion of the G. morsitans belt along the Jebba-Ilorin-Oyo cattle route, which took place during in the late sixties and early seventies, clearly supported his argument. The progress of this advance has been documented by Jordan (1965b), Baldry (1969) and Riordan (1976). The infestation was eventually eliminated by ground application of insecticide in 1974/75.

During the 1970s a number of new surveys of G. morsitans belts were carried out by TTD. Expansion and merger of belts 44 and 47 in southern Sardauna region of Gongola state, on the border with Cameroon, were reported. Mia (TTD, 1978) has noted the disappearance of Belt 25 near Minna, and described substantial reductions in the extent of belts 1 and 24, to the west and east of the Niger. to a fraction of the size indicated on the current distribution maps, and indicated that they were centred on major game and forest reserves in the area.

Surveys carried out by the Jos, Fixed-wing and BICOT Units of TTD (Bourn and Oladunmade, 1980) indicated a similar situation for belt 42, lying between the Jos plateau and the Benue river, which was found no longer to exist east of the Lafia-Makurdi road. This was attributed

to the general opening up of the region by road construction, the extensive settlement of the area by former inhabitants of the Jos plateau, the elimination of wildlife, and the continued northward expansion across the Benue by the Tiv people, who had earlier been responsible for the disappearance of the G. morsitans belt near Wukari, mentioned by MacLennan, (1955) and Ford (1971).

To summarise: Numerous changes have occurred in the distribution of G. morsitans belts in Nigeria over the past 30 years. Although the boundaries of the various belts have often been ill-defined, both advances and recessions have occurred. It is widely accepted that human activity in the form of hunting and cultivation leads to tsetse recessions, by removal of natural hosts and habitats, but there has been some controversy over the significance of the various possible causes for advances. Figure 4.1, however, clearly indicates that the net result of the various changes in distribution which have occurred, has been a substantial and widespread decline in the overall extent of infestation of G. morsitans, both inside the eradication zone, prior to eradication, and in regions where no control or eradication operations have been mounted.

#### 4.3 Changes in G. palpalis and G. tachinoides Distribution.

Changes in the distribution of G. palpalis and G. tachinoides, which in the northern part of their range are closely tied to relatively dense vegetation, have, with one exception, not been well documented.

The exception, which is notable because of the prolonged period of more than 30 years of observation, concerns a population of G. palpalis on the Bahogo stream in the Anara forest reserve, north-east of Kaduna. Nash and Page (1953), Jordan (1965c) and Onyiah (1978) have reported the results at various stages of nearly continuous observation from 1944 to 1976 (with a break from 1950 to 1954) in which fly rounds were carried out every two weeks. Catches varied seasonally, with a peak usually occurring in the late wet season. Until 1969 total annual catches ranged from 600 to 1800, but then began to decline and none were caught in 1975 or 1976.

Although the Bahogo runs through a forest reserve which in principle was protected, substantial poaching, timber felling, and firewood collection had in fact taken place within it. During the period of study, human population in the vicinity had greatly increased, and extensive peripheral cultivation had developed (Popham, 1972).

Nash (1948) quoting unpublished information from 1911 and 1921, which referred to the disappearance of G. palpalis from forest islands, and replacement by G. tachinoides, suggested that the northern limits of their distribution did not remain static.

Baldry (1964, 1966 & 1969a) has described a number of instances of tsetse, particularly G. tachinoides occupying unusual, often man-made habitats in Nigeria, which have variously been described as "atypical", "abnormal", "peridomestic" or "man-adapted", and he considered that there were reasons to believe that a southward extension of G. tachinoides distribution was being facilitated by its peridomestic behaviour, associated with man's development of the coastal forest belt and the keeping of livestock, especially pigs.

#### 4.4 Assessment.

Whilst the changes in Nigeria's tsetse distribution considered in 4.2 and 4.3 would appear to be a rather meagre collection, they have a common underlying cause: the environmental changes brought about by human activity. As will be described in the following chapters, man's impact on the Nigerian environment has been considerable. The examples quoted above are merely those that have been documented, and do not adequately reflect what in reality has been a highly significant and widespread phenomenon.

## 5 AGRICULTURAL EXPANSION AND ENVIRONMENTAL CHANGE IN NIGERIA.

During the twentieth century man has become increasingly aware of the environmental effects of his own activities. The environmental question has entered the political and economic arena and become a subject of widespread debate, concern and publicity in many parts of the world.

In reality, man has been modifying his surroundings since he came into existence, particularly after he controlled the use of fire and became an agriculturalist. It is only relatively recently, with rapidly rising human population levels, improved communications and advances in remote sensing technology, that the widespread nature and long lasting effects of man's impact on the environment have become generally recognised, and some of the consequences begun to be appreciated (Goudie, 1977 & 1981).

Most "developed" industrialised countries experienced a phase of rapid population growth during the eighteenth and nineteenth centuries and passed through their demographic transition only relatively recently, to reach a plateau of more or less stable population size, or at least very low growth rates (Clark, 1977).

"Developing" countries of the third world, on the other hand, are currently experiencing their own phase of rapid population growth. In this respect Nigeria is no exception.

## 5.1 Human Population.

Nobody knows, with any degree of certainty, how many Nigerians there are, but the population is generally recognised to be the largest in Africa, ethnically extremely diverse, and to be growing rapidly.

National censuses have been conducted, with increasing thoroughness in: 1911, 1921, 1931, 1952/53, 1962, 1963 and 1973. But all have been bedevilled by inconsistencies, criticisms of methodology, or claims of fraud and political manipulation, with the result that their findings have been greeted with widespread scepticism. (Udo, 1968; Yusufu, 1968; and Ekanem, 1972). Table 5.1 lists the census results, and various subsequent projections of population size.

Complete enumeration was not possible in the early censuses because of problems of accessibility. In addition, the reliability of the information collected was open to question because of a suggested reluctance on the part of the individual to divulge accurate figures of household membership for fear of legal and tax liability, or on religious grounds. Many of the early returns cannot be considered as anything more than informed guesses.

The 1952/53 census was the first attempt at complete enumeration, but again, for the reasons outlined above, was generally believed to underestimate considerably the actual population size. Subsequent censuses have, if anything, probably suffered from overestimation, largely because, if they were not aware of it before, pre-census publicity campaigns made it clear to Nigerians that, political representation and allocation of government funds were dependent on population size determined from census returns.

TABLE 5.1 NIGERIAN HUMAN POPULATION ESTIMATES AND CENSUS RESULTS.

Year	Source	Region			Lagos	Total
		Northern	Western	Eastern		
				Millions		
1911	Census (a)	8.1	3.4	4.5	0.07	16.1
1921	Census (a)	10.6	3.0	5.1	0.1	18.7
1931	Census (a)	11.4	3.9	4.6	0.1	20.1
1952/53	Census (a)	16.8	6.1	7.2	0.3	30.4
1962	Census		Never published			
1962	Estimate (b)	22.0	6.1	7.1	0.5	45.3
1963	Census (a)	29.8	12.8	12.4	0.7	55.7
1973	Census (c)		Withdrawn			(79.0)
1973/74	Estimate (d)					72.2
1975	Estimates (e)					73 - 77
1975	Estimate (f)					75.0
1979/80	Estimate (d)					86.2

(a)	Ekanem, 1972.	(d)	FAO, 1966.
(b)	Okongo, 1968.	(e)	Olayide, 1976.
(c)	McEvedy and Jones, 1978.	(f)	World Bank, 1977.

Both the 1962 and the 1973 censuses were declared null and void. They were never officially recognised because they were politically unacceptable and were said to have been blatantly rigged. Although the 1963 census was also disputed and strongly criticized, it was nevertheless eventually accepted by the Federal Government. At that time, Nigeria's human population was estimated to be 55,600,000, with eight major ethnic groups of more than one million people each. Their distribution and density are shown in figure 5.1.

More than twenty years have elapsed since the last recognised census was taken. Estimates of present day population levels depend on the assumed growth rate over the intervening period, which may vary regionally and has not been well documented. An overall 2.5% growth rate has usually been applied, which would give a 1983 population of 91 million. Higher growth rates have been recorded in Kenya and Zimbabwe. If 3.5% were assumed, a population doubling time of 20 years, then the present population might be 110 million. A growth rate of 2% would give a population of 83 million.

Given the questionable nature of the 1963 census data, the uncertain growth rate, and the time elapsed, estimates of Nigeria's present population must remain largely a matter of conjecture.

It follows that the distribution of human population is similarly uncertain; particularly in view of population mobility, which although again not well documented is generally recognised to be substantial, both from rural to urban areas, and also between rural regions (Udo, 1975; and Ajaegbu, 1976).

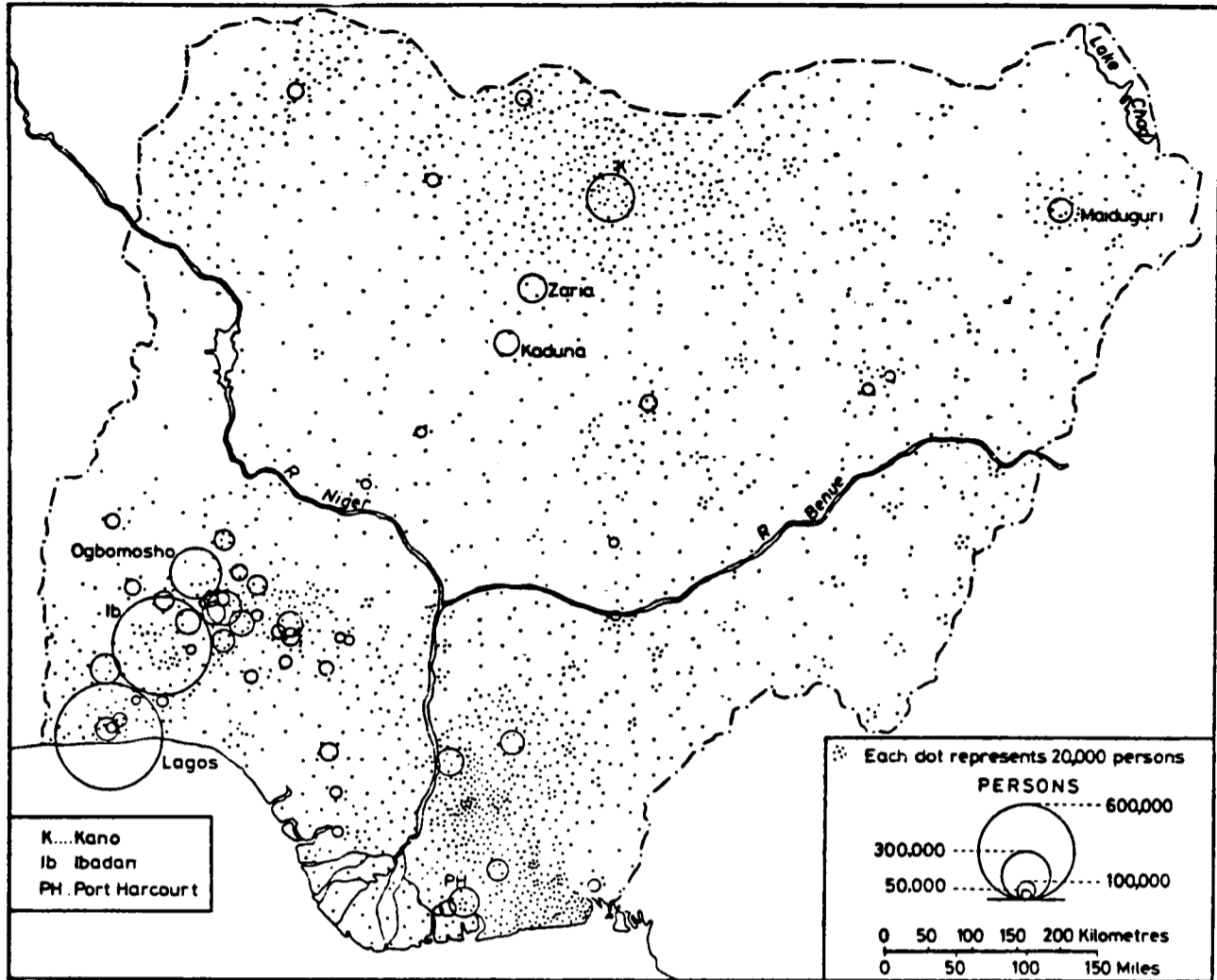
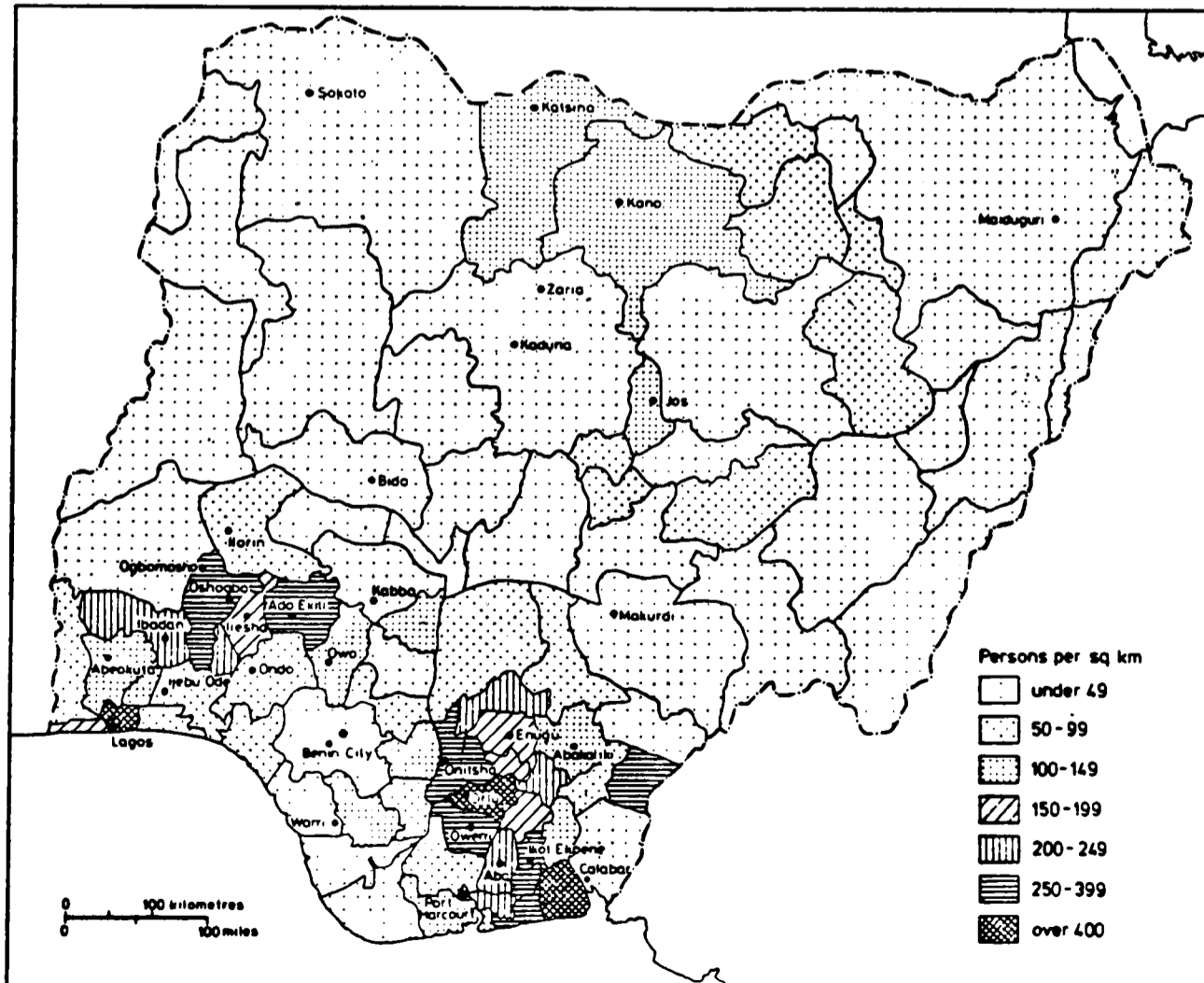


FIGURE 5.1 : HUMAN POPULATION DISTRIBUTION AND DENSITY - 1963 CENSUS  
( AFTER AFOLAYAN, 1978 )



## 5.2 Land Use Intensity in Central Nigeria.

Although Nigerian census information is an unreliable guide to present population size and distribution, a good indication of man's environmental impact, and an indirect measure of his overall distribution can be obtained by remote sensing.

Interpretation of aerial photography reveals not only geographical details such as topography, river courses and the location of roads, tracks and settlements; but also the extent of agricultural land, and the boundaries of natural vegetation.

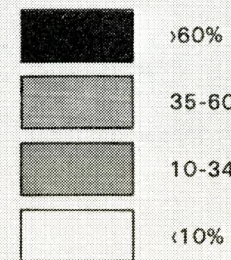
During a land resource study of central Nigeria (LRDC, 1979a) many tens of thousands of aerial photographs, taken during the early 1970's, were examined, and land use classified under a system described by Brunt (1967). An atlas of resource maps was also produced (LRDC, 1981), covering an area of 230,000 square kilometers stretching from the border with the Republic of Niger in the north, to south of the Benue valley. The atlas includes a map of Present Land Use, which is reproduced as figure 5.2. It shows the proportion of land within the cultivation cycle (i.e. actively cultivated plus fallow land), as it was in the early 1970's.

The density of cultivation, which can also reasonably be taken as an indication of the degree to which man has modified the natural vegetation in his local environment, was categorised into four classes: < 10%; 10 - 34%; 35 - 60% and > 60%.

FIGURE 5.2 : PRESENT LAND USE

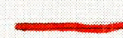
Scale 1:1,500,000

Density of cultivation, i.e. percentage of land within the current cultivation cycle



Forest reserve boundary

Main road



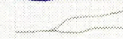
Secondary road



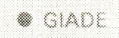
Railway



Watercourse



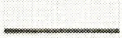
Town



International boundary



Project boundary

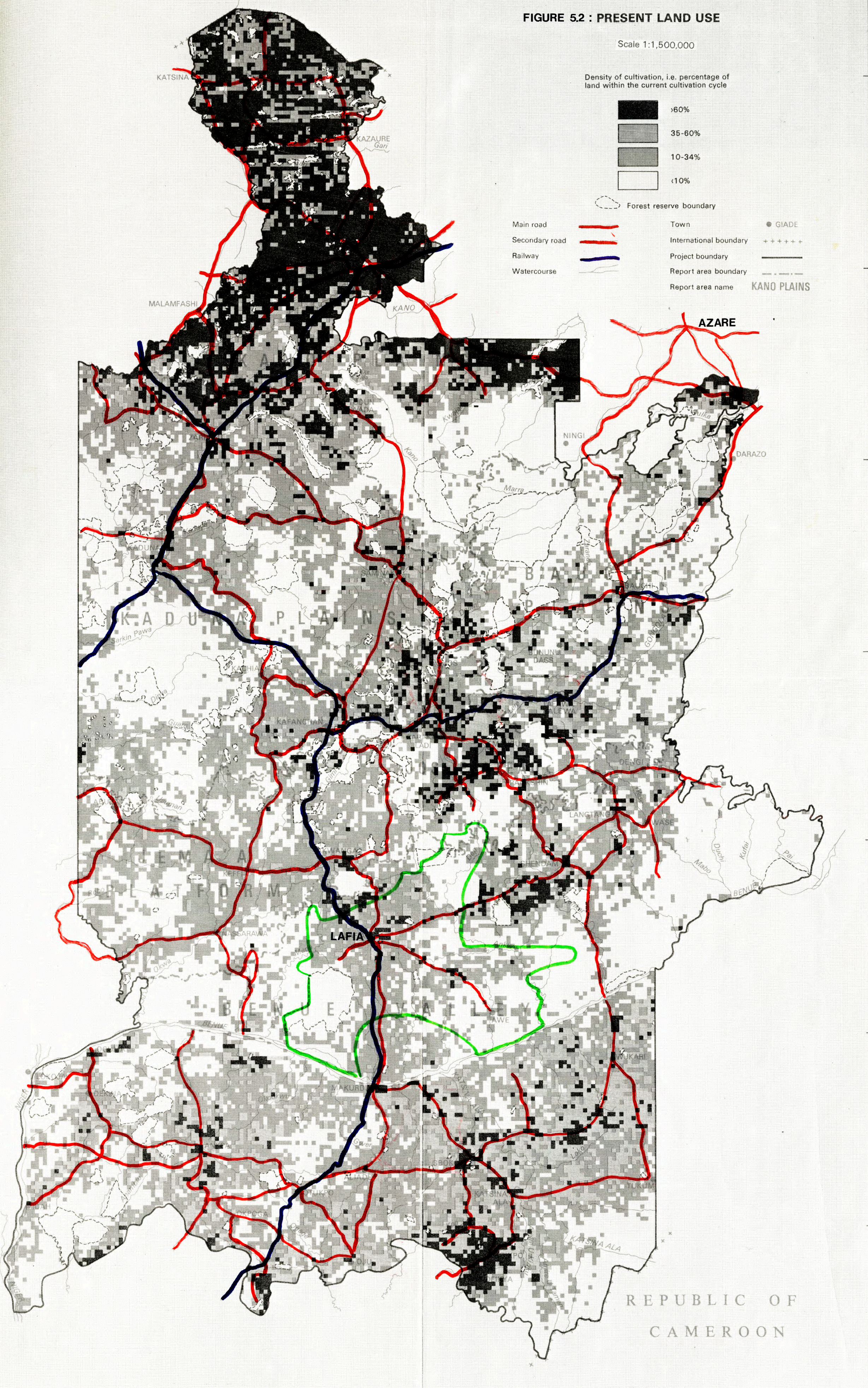


Report area boundary



Report area name

KANO PLAINS



REPUBLIC OF CAMEROON

It is obvious from figure 5.2 that Kano state in the north had the most extensive, and highest density of cultivation. Further south, cultivation was generally more scattered and at medium density levels. However, both on the Jos plateau and in the region south of the Benue river, cultivation was generally at higher levels and more extensive. Regions with little or no cultivation occurred to the west of Ningi, to the south of Kaduna, and in areas immediately north of the Benue river.

### 5.3 Roads and Railways.

An interesting and significant feature revealed by the map in figure 5.2 is the good correspondence between the distribution of cultivated land and the network of major roads and railways. Conversely it can also be seen that in areas of low intensity land use, road and rail communications are poor. Minor roads and tracks are not shown, but although they are far more numerous than major roads, their pattern is closely associated with the major road network which they feed. Whilst the primary objective for establishment of road and rail networks may have been to link agricultural, economic, industrial and political centres, the construction of new roads also acted as a catalyst for agricultural settlement.

Where land use intensity is high (e.g. in the northern and southern parts of Nigeria), or where soil fertility has been impoverished by prolonged cultivation (e.g. the Jos plateau), and where rural populations continue to increase, land available or suitable for cultivation becomes scarce, and there is greater motivation for individuals to move. Newly constructed roads through previously

remote and inaccessible areas, with land otherwise suitable for farming, tend to channel migrant farmers into areas where competition for land is reduced, and thereby to focus agricultural activity in their vicinity.

In the first instance, if wildlife is present, hunting is likely to be economically rewarding, and land clearance for cultivation will yield an abundant supply of firewood for roadside sale; subsequently farm produce may be consumed or sold locally, or sold further afield.

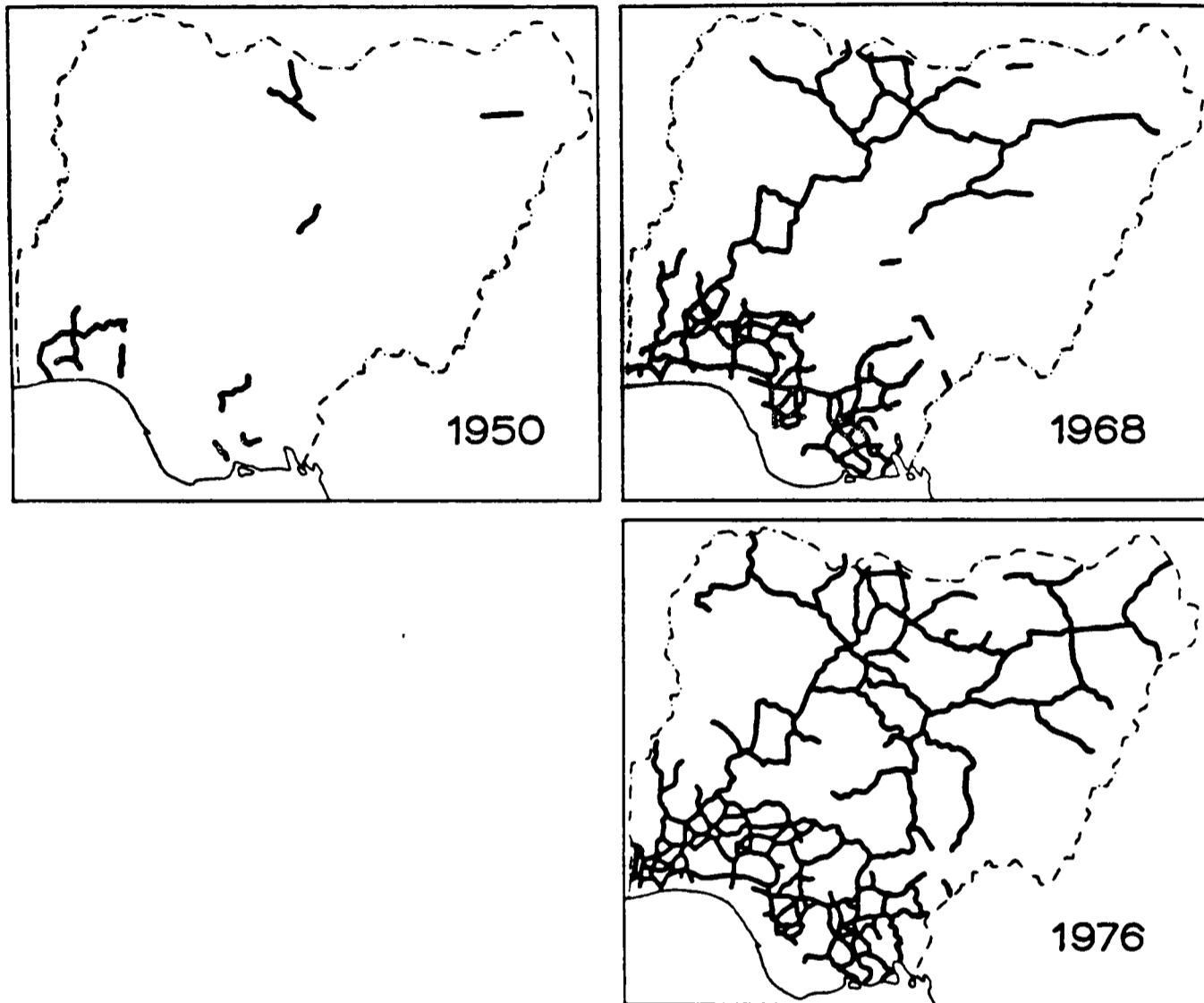
An indication of how Nigeria as a whole has been "opened up," and how accessibility, for both producers and consumers, has been improved over the past 75 years by development and expansion of a network of major roads, is illustrated in figure 5.3.

#### 5.4 Vegetation and Land Use Patterns.

LRDC's (1981) present land use map of central Nigeria covers approximately a quarter of the country. No similar maps have been produced for the rest of Nigeria, and one of the problems facing cartographers attempting to map southern Nigeria has been the persistent and extensive cloud cover, a characteristic of coastal and forest zones, which has limited the usefulness of both aerial photographic surveys and LANDSAT imagery.

An alternative, newly developed remote sensing technique, involving the use of side looking airborne radar (SLAR), which has an all weather, cloud penetrating capability, has recently (1976/77) been employed to provide up to date and complete coverage of the whole of

FIGURE 5.3 : EXPANSION OF MAJOR ROAD NETWORK 1950-1976  
( AFTER O'CONNOR, 1978 )



Nigeria (Hunting, 1978). This imagery, together with available LANDSAT imagery, the most recent conventional aerial photography, and extensive ground verification, was used to produce 69 vegetation and land use maps at a scale of 1:250,000 (FDF, 1978).

A single composite vegetation and land use map of the whole of Nigeria was unfortunately never made, so in order to illustrate the extent and intensity of present day agricultural activity, a much simplified map has had to be traced by hand from crudely photo-reduced prints of the original 69 maps (see figure 5.4). Whereas the original printed maps show a total of 45 separate vegetation and land use categories, this has been reduced to the following seven on the composite map: grassland; thicket and shrubland; woodland; forest; mangrove; and farmland; with the latter being divided into: >60% intensity, and 30% to 60% intensity.

Although a substantial amount of detail has of necessity been lost in the reduced composite map it does give a good general indication of both the widespread impact of agricultural activity, and the distribution of Nigeria's human population.

Extensive areas of medium to high levels of land use intensity are found in northern Nigeria, stretching round in a more or less continuous arc of varying width from Mayo Faran in the east, through Gombe, Potiskum, Kano, Zaria, Katsina, Gusau, Funtua to Sokoto in the west, with highest cultivation density being associated with major towns, and in particular Kano state and northern Kaduna state (formerly Katsina province).

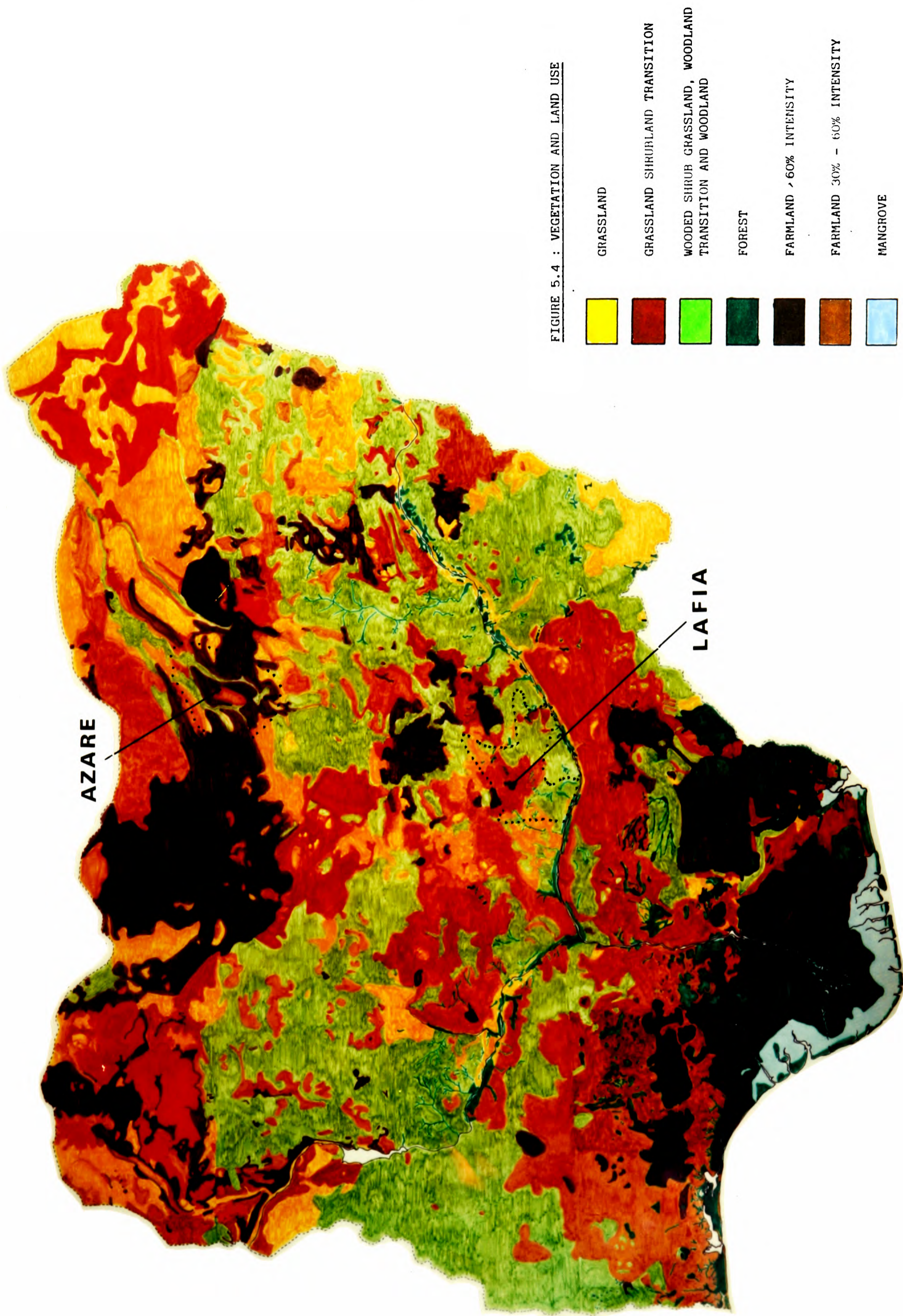


FIGURE 5.4 : VEGETATION AND LAND USE

- GRASSLAND
- GRASSLAND SHRUBLAND TRANSITION
- WOODED SHRUB GRASSLAND, WOODLAND TRANSITION AND WOODLAND
- FOREST
- FARMLAND > 60% INTENSITY
- FARMLAND 30% - 60% INTENSITY
- MANGROVE

In the south, a similar band of extensive cultivation from Lagos, Ibaden and Ilorin in the west, stretches north of the Niger delta and south of the Niger-Benue fork, to Katsina Ala and Wukari in the east.

The land in between these two regions of extensive cultivation falls within the boundaries of what has been named "the middle belt", or "the sub-humid zone". Here the pattern of vegetation and land use can best be described as a mosaic of regions of medium to high levels of cultivation, grassland, and woodland. An interconnecting patchwork of cultivation links the northern and southern cultivated regions of Nigeria, through a broad belt north of Lokoja including Bida, Minna, Abuja, Lafia, Shendam, Kafanachan, the Jos plateau, Kaduna and Saminaka. The LRDC (1981) land use map for central Nigeria (figure 5.2) covers this bridging zone. To the west and east, cultivated areas are generally more scattered with woodland vegetation tending to predominate.

#### 5.5 Agricultural Expansion and Environmental Change.

Both the present land use map of central Nigeria (figure 5.2) derived from air photo-interpretation, and the land use map of the whole of Nigeria derived from SLAR imagery (figure 5.4), give an indication of conditions at effectively fixed points in time during the 1970s when the remote sensing took place. Although they suggest substantial man induced changes to the Nigerian environment in general and natural vegetation patterns in particular, without knowledge of prevailing conditions at an earlier time, it is not possible to quantify the rates of change that have taken place.

With this in mind, and also in order to compare vegetation and land use changes that had taken place inside and outside the tsetse eradication zone, a comparative air photo interpretation study of sequential sets of aerial photographs for two separate areas of Nigeria, was carried out. The choice of study areas was limited by the availability of suitable photographic coverage, and relevant information concerning human and livestock populations. The two areas selected are indicated in figures 5.2 and 5.4.

### 5.5.1 Study Areas.

#### 5.5.1.1 Azare.

This area, centred on the town of Azare, covers approximately 9,000 square kilometers of land within the Sudan vegetation zone, between longitudes  $9^{\circ} 30'$  -  $11^{\circ} 00'E$  and latitudes  $11^{\circ} 30'$  -  $12^{\circ} 30'N$ . It lies close to the former northern limits of tsetse distribution within the Chad drainage basin, and two rivers, the Katagum and Komadugu Gana, run north-eastwards through the area. G. morsitans and G. tachinoides used to occur here, but were eliminated during the tsetse eradication operations which took place between 1955 and 1964, summarised by Davies (1964).

Two sets of 1:40,000 air photographs were available for examination; one set flown in 1950, five years before the onset of the eradication programme; and the other, some twenty years later, between 1969 and 1971. A total of 790 photographs were examined.

Today the Azare study area forms part of the Gamawa and Azare local government authorities of Bauchi state and includes the following districts: Azare, Gadau, Gamawa, Itas, Jamaari, Katagum and Sokwa. The mean annual rainfall is approximately 750mm, with a dry season extending from November to April. The major crops grown are millet, sorghum and beans. Groundnut and cotton production has declined in recent years, while cultivation of rice, tomatoes and chilli peppers has increased along moister drainage lines.

Population estimates for both man and livestock leave much to be desired, but available information collected by Putt et al. (1980), based on tax return and national census figures, indicate that human population growth rate was between 4.4% and 5.2% per annum during the period 1952/53 to 1976/77; with an increase in human population density from 32 per square kilometer in 1952/53 to 56 per square kilometer in 1963. Cattle population growth rate has averaged 3.1% per annum over the period 1962/63 to 1972/73.

#### 5.5.1.2 Lafia.

This area, centred on the town of Lafia, south of the Jos plateau, covers a total of some 9,400 square kilometers of land in the southern Guinea vegetation zone, in the lowlands of the Benue valley, between longitudes 8°00' - 9°00'E and latitudes 8°00' - 10°00'N.

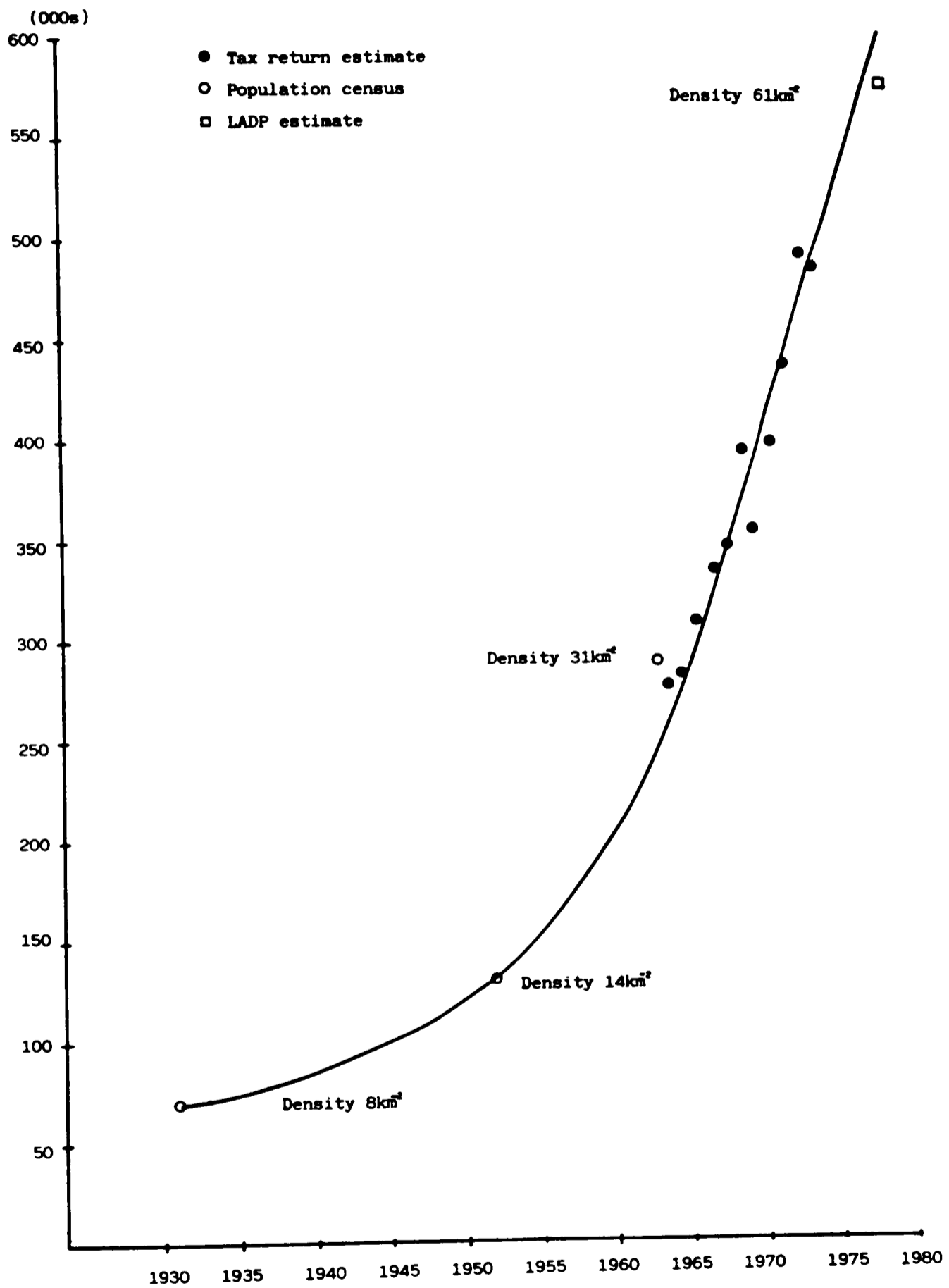
In contrast to the Azare area, the tsetse eradication programme has yet to reach Lafia, although some fixed-wing trials were carried out in 1976 over the Doma forest reserve in the extreme west of the study area; and some limited tsetse control ground spraying has taken place

around Shabu, a persistent focus of human sleeping sickness. The Lafia area lies well within the distribution limits of G. morsitans and G. tachinoides, and close to the eastern boundaries of G. palpalis and G. longipalpis distribution. According to current tsetse distribution maps, much of the area lies within the conjectural boundaries of G. morsitans, but as mentioned in the previous chapter, this belt no longer exists east of the Lafia to Makurdi road. As described in the following chapter, the remaining three species are confined to very limited areas of forest vegetation amounting to some 5% of the land area, with G. longipalpis having the most restricted distribution.

The two sets of 1:40,000 aerial photographs available for comparison were taken ten years apart, in 1960 and 1969/70. A total of 750 photographs were examined.

Today the Lafia area is administered by the Lafia and Awe local government authorities and is composed of Awe, Assaikio, Doma, Keana, Lafia and Obi districts. The whole area lies within the Lafia Agricultural Development Project. Mean annual rainfall is approximately 1200mm and the dry season extends from November to March. The major crops grown are yams, sorghum, millet and cassava. Human and livestock population statistics are of a similar uncertain quality as those for Azare. They indicate a human population growth rate ranging from 4.1% to 5.7% per annum for various periods between 1931 and 1978 (see figure 5.5), with an increase in average human population density from 13 to 25 per square kilometer in the period between the official censuses held in 1952/53 and 1963; cattle tax returns indicate an average of 5.5% per annum rate of increase between 1956/57 and 1970/71 (Putt et al. ,1980).

FIGURE 5.5 : HUMAN POPULATION INCREASE IN THE LAFIA AREA 1931 - 1978



### 5.5.2 Detection of Change.

A slightly modified land use categorisation and random point method of sampling aerial photographs (Brunt, 1967), was used. On each photograph there is a normal overlap between consecutive prints of the same survey of about 65%, and between adjacent runs of about 25%, leaving a central area, around its principal point, unique to each photograph. This area was sampled by means of a transparent overlay, marked with a series of randomly placed dots, each dot signifying a point sample. The number of points sampled obviously determines the accuracy of any subsequent estimate. 26 sample points were used on each photograph, which gave land use estimates with a 5% margin of error, in 95% of cases.

Each aerial photograph was examined through a binocular mirror stereoscope and each of the 26 sample points allocated to one of the following six predetermined land use categories:

CATEGORY	CHARACTERISTIC
<u>Active Cultivation</u>	Distinct field boundaries, exposed soils and no evident regrowth.
<u>Young Fallow</u>	Field boundaries clear, but some regrowth evident; less than three years old.
<u>Old Fallow</u>	Field boundaries faint with pronounced regrowth; more than three years old.
<u>Uncultivated Woodland</u>	> 50% scrub and tree cover.
<u>Uncultivated Grassland</u>	> 50% grass cover.
<u>Settlements and Roads</u>	Self evident.

The basic land use information thus derived was recorded for both earlier and later sets of aerial photographs of the Azare and Lafia areas. Together with other mapping and survey details this information was analysed using a Land Resources Development Centre computer programme (LRDC, 1979b), to provide an output of the initial and subsequent percentages of each land use category, and of the total percentage change that had occurred in each area.

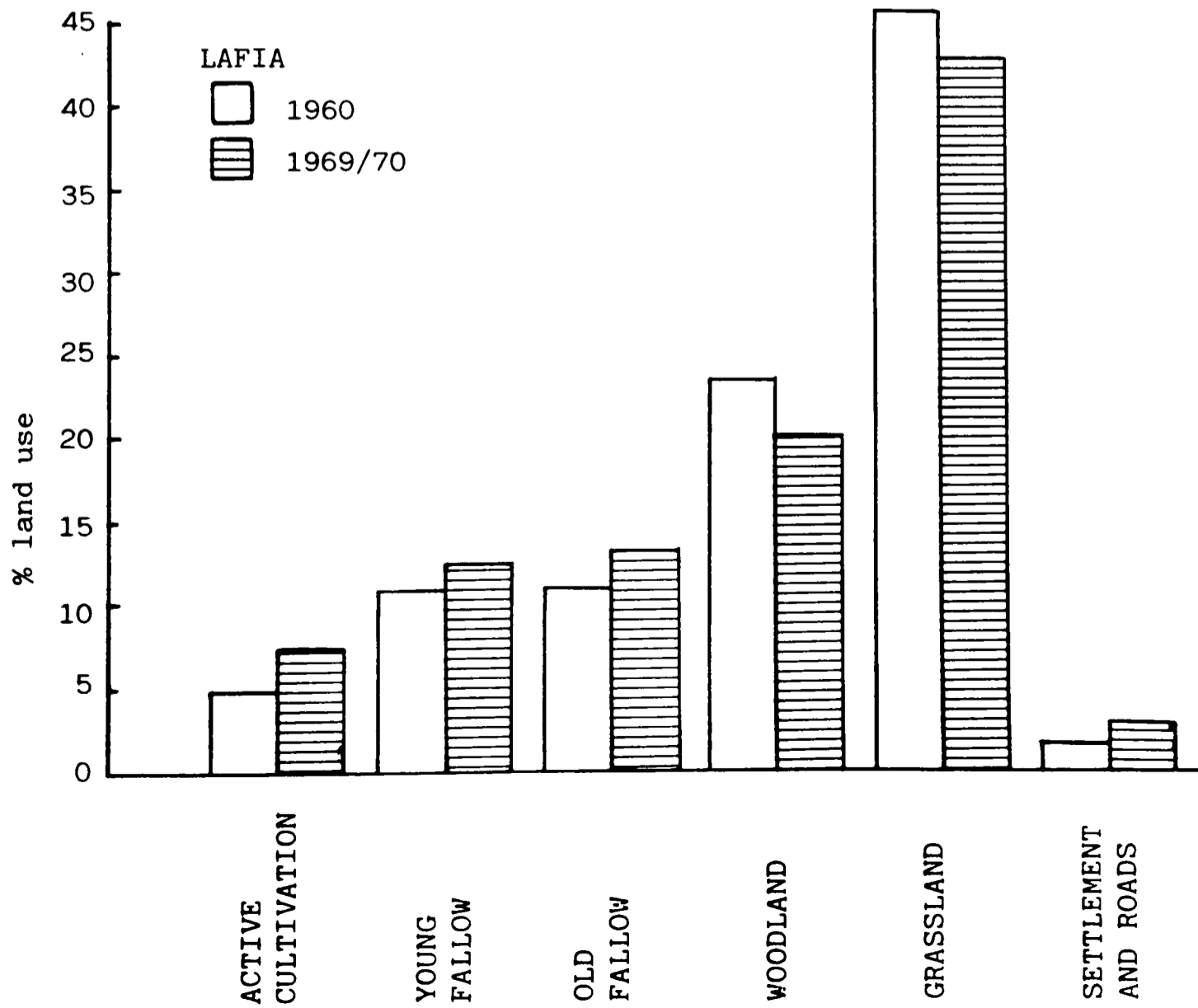
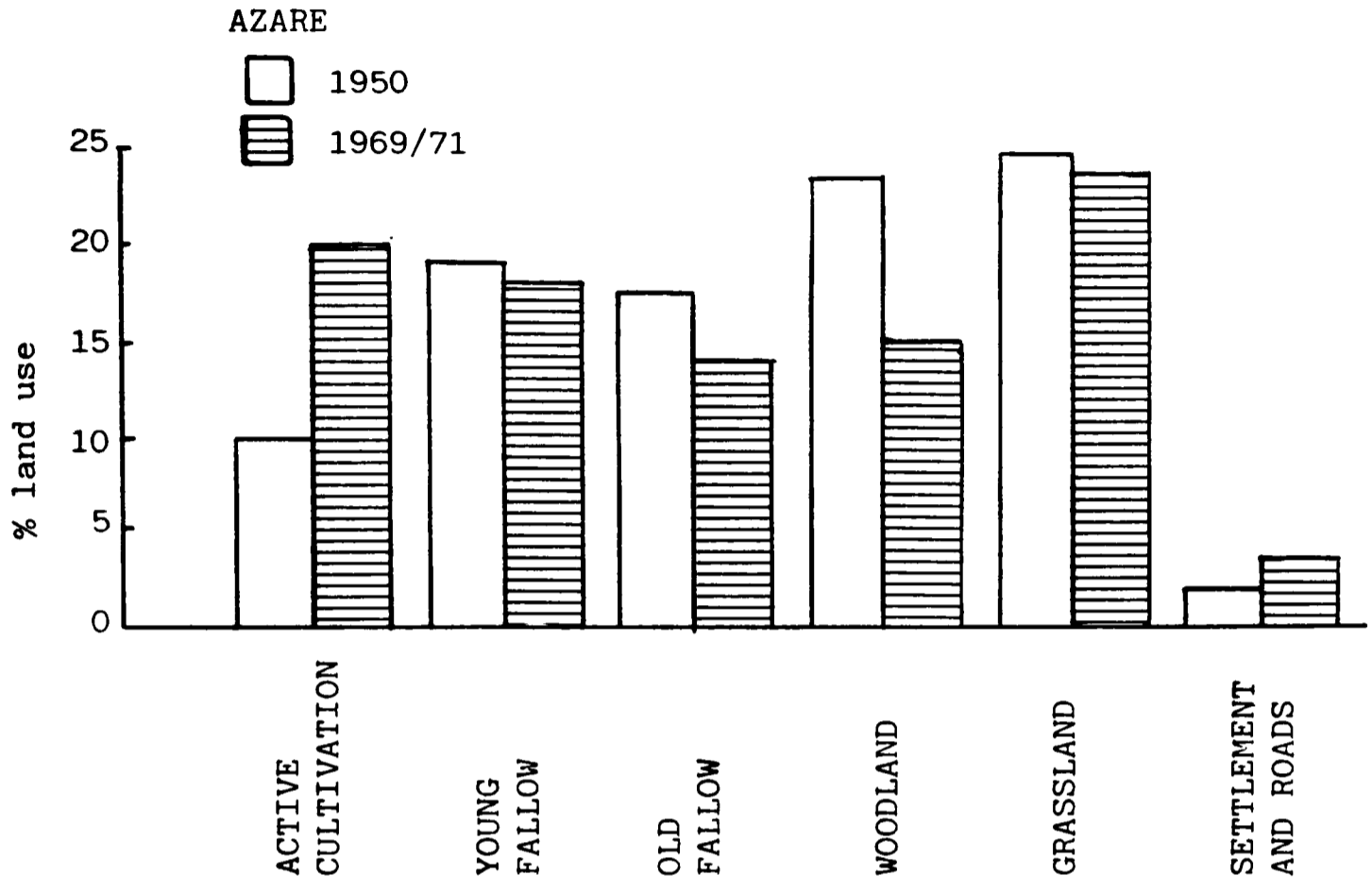
### 5.5.3 Changes in Vegetation and Land Use.

The results of the vegetation and land use analysis are shown in figure 5.6. The interval between the aerial surveys was 20 years for the Azare area, and nine to ten years for the Lafia area. Comparison of the changes that had taken place in the two areas can not, therefore, be made directly. However, as the later photographic coverage for both was flown in 1969/70, comparison of the vegetation and land use proportions at that time is justified.

In 1969/70, 52% of the Azare area, and 33% of the Lafia area, was or had recently been cultivated (active cultivation plus young and old fallow). Woodland covered a little more of the land area in Lafia (20%), than in Azare (15%); while grassland was considerably more abundant in Lafia (43%) than in Azare (24%). Settlements and roads occupied similar proportions in both areas: 4% in Azare, 3% in Lafia.

The districts with the highest proportions of active cultivation in the Azare area were: Jamaari (32%); Itas (32%); Gadau (29%); and Azare (29%); in the Lafia area they were: Lafia (25%) and Assaikio (23%).

FIGURE 5.6 : CHANGES IN VEGETATION AND LAND USE



In the Azare study area over the twenty years between 1950 and 1970, the overall extent of land under active cultivation doubled (from 9% to 20%), greatest changes taking places in those districts with the highest levels of active cultivation mentioned above. This agricultural expansion took place largely at the expense of woodland which decreased from 23% to 15%. Total land area within the cultivation cycle, however, increased only slightly from 46% to 52%. The apparent inconsistency in changes in active and total cultivation is explained by the reduction in the proportions of both young and old fallow, which is indicative of a decline in fallowing period and of more intensive cultivation. The extent of settlement and roads also doubled from 2% to 4%, which presumably reflects increases in both human population, and accessibility.

In the Lafia study area, over the nine to ten years between photographic surveys, the overall extent of active cultivation increased by half, from 5% to 7.5% of the land area, again with the greatest increases occurring within those districts with the highest proportion of active cultivation (Assaikio and Lafia). Young and old fallow also increased, resulting in an overall increase in the proportion of land within the cultivation cycle from 27% to 33%, at the expense of both woodland and grassland, which declined from 24% to 20%, and 46% to 43%, respectively. Settlements and roads increased during the period from 1% to 2%.

For comparative purposes, taking into account the differences in the interval between the two sets of aerial photographs for the two areas, compound annual rates of change for each of the vegetation and land use categories were calculated. These are given in table 5.2, together with estimates of the growth rates of human and cattle populations.

TABLE 5.2 RATES OF CHANGE IN LAND USE, HUMAN AND CATTLE POPULATIONS.

	Azare	Lafia
Dates of aerial photography	1950 and 1969/71	1960 and 1969/70
Date of tsetse eradication	1955 - 1962	-
Mean annual rainfall mm	500 - 750	1,000 - 1,250
Vegetation zone	Sudan	Southern Guinea
Area square kilometers	9,000	9,400
Human population density per square kilometer		
1952/53 census	32	13
1963 census	56	24
	Compound rates of change per year	
Land Use Categories		
Active cultivation	+3.8	+4.8
Young fallow	-0.2	+1.5
Old fallow	-1.4	+2.1
Woodland	-2.1	-1.8
Grassland	-0.2	-0.8
Settlement and roads	+3.1	+4.6
Human population	+4.4 (a) +4.7 (b) +5.2 (c)	+4.1 (d) +4.5 (e) +5.7 (c)
Cattle population	+3.1 (f)	+5.5 (g)
<p>(a) District tax returns 1957/58 to 1976/77.            (b) District tax returns 1957/58 to 1965/66.            (c) National census 1952/53 to 1963.            (d) Lafia division tax returns 1963/64 to 1969/70.            (e) 1931 census to 1978 LADP estimate.            (f) Cattle tax returns 1962/63 to 1972/73.            (g) Cattle tax returns 1956/57 to 1970/71.</p>		

As previously explained, the reliability of estimates of human population size based on tax returns is uncertain, and indeed the growth rates determined from them are high: 4.4% to 5.2% per annum for Azare, and 4.1% to 5.7% per annum for Lafia. However, both growth rates are in line with the observed rates of expansion of active cultivation in the two regions: 3.8% and 4.8% per annum respectively. They are also consistent with the observed rates of increase in settlements and roads: 3.1% and 4.6% per annum. These results would suggest that it is probable that, in addition to natural population growth, both Azare and Lafia have experienced a net immigration of people during the periods concerned.

Although the proportion of land actively cultivated in Azare was considerably higher than in Lafia, the declining proportion of fallow in Azare is indicative of a shortage of virgin land suitable for farming; while in Lafia the increase in fallow land indicates an abundance of virgin land available for agricultural expansion.

Whilst there are obvious differences in the two areas considered: rainfall, natural vegetation zone, agricultural practices, and the presence of tsetse in Lafia and their eradication from Azare; both areas have experienced fundamentally similar environmental changes, and show similar rates of human population growth and agricultural expansion. Indeed, contrary to expectations, it would appear from the available figures that, despite the presence of tsetse, cattle populations have increased more rapidly in the Lafia area (5.5% per annum) than in Azare (3.1% per annum), which may be a reflection of the higher proportion of uncultivated land available for grazing during the wet season in the Lafia area.

The present day distributions of tsetse and cattle in the northern part of the Lafia area are examined in more detail in chapters 6 and 7.

## 5.6 Deforestation.

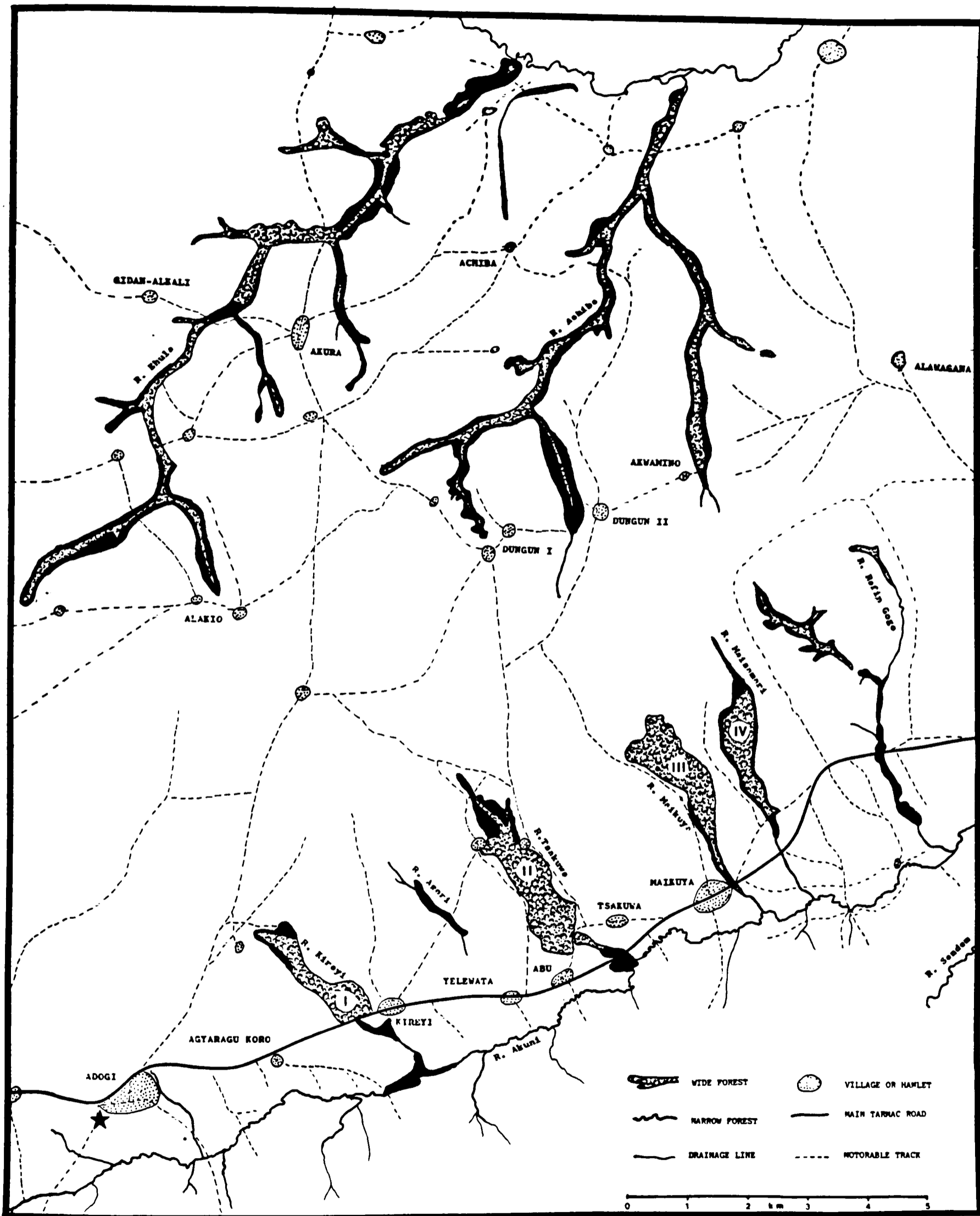
In the preceeding section, overall environmental change has been considered in two different areas of Nigeria in terms of the changing proportions of major land use categories. The proportion of land covered by riverine forest vegetation in both areas was generally so low that it was not differentiated as a separate vegetation and land use category.

In the northern part of the Lafia area, which was selected as the project area for the Biological Control of Tsetse (BICOT), riverine forest occupied some 5% of the land area, and was the primary habitat in which tsetse were found (see chapter 6).

During the course of an aerial survey of cattle within the BICOT project area in 1982, a series of high altitude vertical photographs were taken of selected riverine forest habitats, in order to update project maps which were based on 1973/74 aerial photography.

Comparison of the 1973/74 and 1982 photography clearly shows the extent of agricultural encroachment of riverine forest that has recently taken place. The areas of more extensive riverine forest removal are indicated in black in figure 5.7. Within the mapped area, which lies in the centre of Assaikio district and had a land use intensity of 50% to 70% (LRDC, 1979a), an estimated 20% to 25% of the riverine forest had disappeared between 1973/74 and 1982. This amounted to an annual rate of deforestation of 2.8% to 3.5%, resulting directly from human activity, mainly in the form of cultivation, but also to some extent due to extraction of valuable timber. This rate of forest removal is in line with other forms of environmental change observed for the Lafia area as a whole (section 5.5.3).

FIGURE 5.7 : DEFORESTATION WITHIN BICOT PROJECT AREA, 1973/4 TO 1982



Deforestation is a world wide phenomenon. In Nigeria it has been of long standing occurrence, and is widespread. Rosevear (1953) commented that zoological collectors were unlikely to find any totally undisturbed rain forest in Nigeria. Thirty years ago, in recognition of the significant influence that man had had on Nigerian vegetation, Keay (1953) classified an extensive zone of savanna vegetation as being "derived" from rain forest, large tracts of which could still be found further south.

Since then, the processes of change have continued apace. Miller and Williams (1979), in a LANDSAT study of a 7,000 square kilometer region of Nigeria east of Lagos and Ibadan, commented that the natural rain forest had been removed from the whole area, except for six small forest reserves, each ranging in size from 50 to 100 square kilometers. They also demonstrated that substantial deforestation had taken place within the forest reserves themselves.

White (1983) has acknowledged that there are now virtually no extensive areas of natural rain forest, unaffected by human influence, left in Nigeria.

#### 5.7 Decline in Wildlife.

"As human populations have increased, former centres of low population have become densely populated, with the surroundings becoming subject to more intensive hunting. There has also been improved mobility resulting from extensive road construction and easier access to remote areas by vehicles. These developments have inevitably led to more and more animals being removed. Furthermore, as local hunting is an

ongoing activity its continuity ensures a constant pressure on the species being removed..... The main factor responsible for the low numbers of large mammals in West Africa is illegal local hunting" (Delany and Happold, 1979).

This general statement for West Africa, is particularly true for Nigeria, where wildlife is very scarce. "Bush-meat" is a highly regarded food supplement, for which people are prepared to pay substantial amounts. During the course of three years field work on the BICOT project the sum total of wildlife I saw was: one family of four warthogs; a number of snakes, which were killed on the spot; a few monkeys; and one bushbuck which was being shot at, and chased by local hunters.

Some wildlife of course does survive in the remoter regions; Yankari and Borgu Game Reserves being good examples where, at least in the former, game is still abundant. Recently, the status of a number of forest reserves has been converted to that of wildlife reserves or game parks. The earlier protection of forest reserves having also often conferred a degree of protection to wildlife. Over most of Nigeria, however, agricultural expansion and prolonged hunting has eliminated virtually all large wildlife species.

#### 5.8 Assessment.

Although the environmental impact of agricultural expansion resulting from Nigeria's large and growing population has been recognised in many quarters, the processes involved and their implications have on the whole been poorly documented and rarely quantified.

The examples considered here: the Azare study, in the northern Sudan vegetation zone; the Lafia study, in the southern Guinea vegetation zone; and Miller and Williams' (1979) LANDSAT study in the southern rain forest zone; demonstrate that agricultural expansion is taking place over a wide range of Nigerian environments, and that the observed rates of change in specific areas are similar to those estimated for human population growth.

In the foreseeable future Nigeria's population is bound to increase, and is almost certain to double in the next 20 to 30 years. Agricultural expansion must also be expected to continue, and so must the processes of environmental change.

The pattern of vegetation and land use in Nigeria (figure 5.4) is far from uniform. Extensive areas of medium to high density cultivation exist in the north and south, with a central bridging mosaic of moderately high levels of cultivation, woodland and grassland stretching between the two. To the east and west of this central zone, low cultivation densities occur and woodland tends to predominate.

It would appear that the expansion of cultivation within this bridging zone, across what was previously regarded as the relatively sparsely populated and undercultivated middle belt of Nigeria (Buchanan and Pugh, 1955; and Pullan, 1962), has followed a general increase in human population levels, resulting from both natural growth and immigration from regions of high human density in the north, south and on the Jos plateau (Bohannon and Bohannon, 1953; and Udo, 1975).

With the inevitable increase in future human population levels in all regions of Nigeria, and the increasing pressure for more agricultural land, particularly in the north and south; it is suggested that in the years to come cultivation density in the central bridging zone north of the Niger-Benue fork will increase, and that the area will be transformed into a region of more or less continuous cultivation. The siting of the new Federal Capital Territory at Abuja, more or less in the middle of this zone, and the developments associated with it, in particular road construction, can only encourage this process. Increasing land shortage within the central zone will eventually lead to agricultural expansion outwards into the, presently, predominantly woodland areas to the west and east.

This scenario for human population growth and agricultural expansion, and the consequent environmental changes, that are occurring and will continue to take place, have wide ranging implications for agricultural development planning. The Nigerian Federal Livestock Department has a policy of encouraging the relocation of the national cattle herd in more southerly latitudes (David West, 1981), and has placed a high priority on the expansion of the tsetse eradication programme. The International Livestock Centre for Africa has recently begun a study of the livestock production system in this part of Nigeria, which has been designated the sub-humid zone (ILCA, 1979).

In the following chapters the effects of man's environmental impact on the distribution and abundance of tsetse and cattle, are considered for a central region of the Nigerian sub-humid zone.

6 TSETSE DISTRIBUTION AND ABUNDANCE IN A REGION OF THE NIGERIAN SUB-HUMID ZONE, NORTH-EAST OF LAFIA, PLATEAU STATE.

Chapter 5 examined changes in vegetation and land use that had occurred as a result of human population increase and agricultural expansion in two areas of Nigeria: Azare, in the northern part of the country, within the tsetse eradication zone; and Lafia, in the middle belt or sub-humid zone, south of the Jos plateau and outside the tsetse eradication zone.

The boundaries of the Lafia area were those of the Lafia Agricultural Development Project (LADP), which occupied some 9,400 square kilometers north of the Benue and west of the Dep river. Amongst a variety of other objectives LADP was responsible for the establishment of cattle grazing reserves, one of which was to be located near Assaikio. The prospects of improved extension services, increased agricultural inputs, and the encouragement of livestock development were important criteria used by the Federal Department of Pest Control Services in its selection of the northern third of LADP, including the proposed Assaikio grazing reserve, as the field area for a project to demonstrate the Biological Control of Tsetse (BICOT), by the release of sterile males, (Bourn and Oladunmade, 1980).

This chapter considers the results of the preparatory field work carried out by BICOT in 1980 and 1981, prior to initiation of tsetse control operations, and includes an examination of environmental conditions; a description of tsetse population sampling procedures; an analysis of tsetse distribution; and an assessment of absolute estimates of G. palpalis population abundance. Details of the subsequent pilot sterile male release programme, and a summary of tsetse infection rates are given in appendix 1 and 2 respectively.

## 6.1 Environment.

### 6.1.1 Geographical Setting.

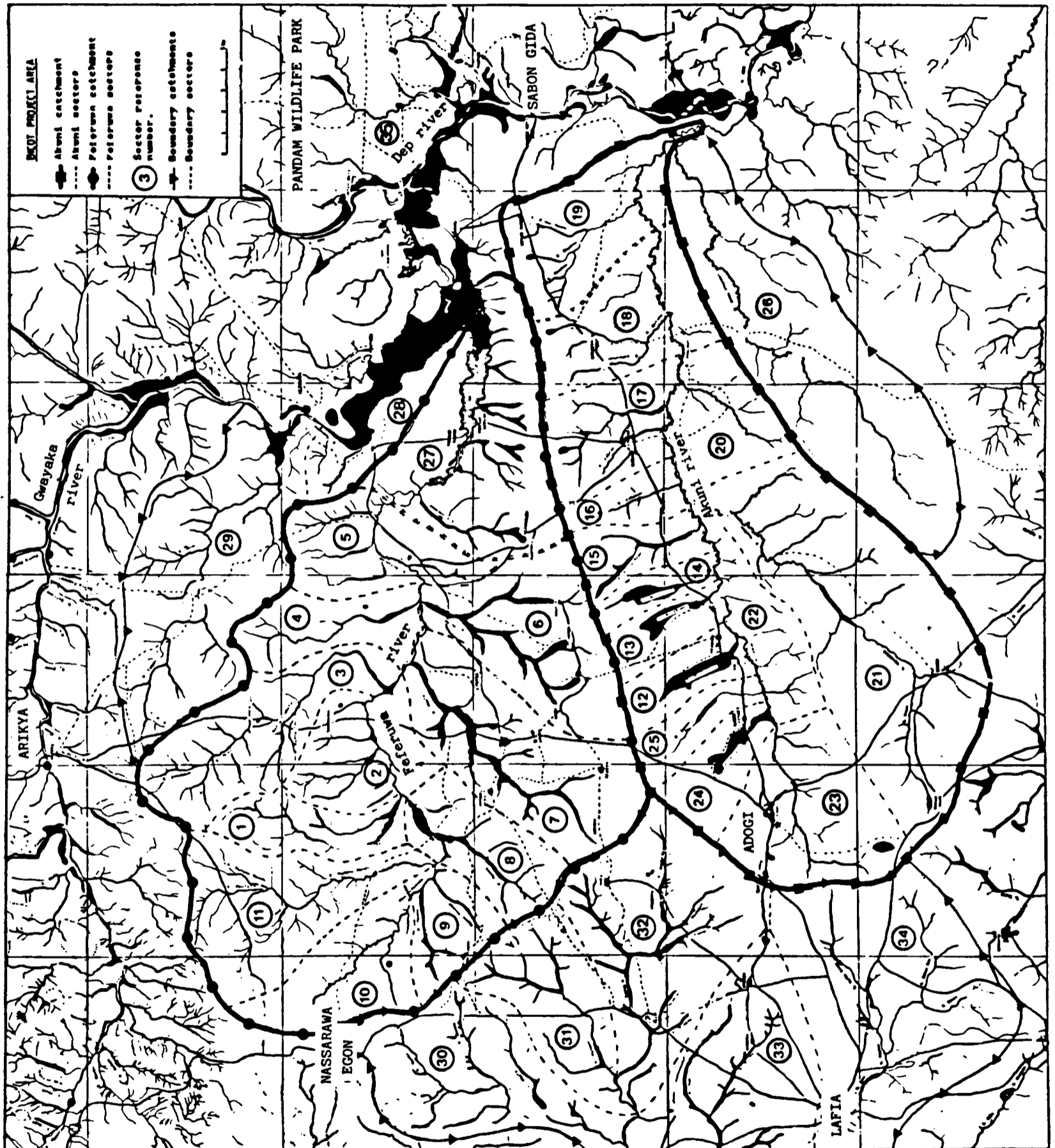
The designated BICOT project area was a 2,500 square kilometer block of land (see figure 6.1) to the north-east of Lafia town ( $8^{\circ}30'N$ ;  $8^{\circ}30'E$ ). The terrain was generally flat or gently undulating, and ranged from 125 to 250 meters above sea level. The Gwayaka and Dep rivers lay on the northern and eastern boundaries, with Pandam Wildlife Park on the opposite bank of the Dep. The Feferuwa and Akuni catchments formed a central core surrounded by various boundary catchments, which had a combined land area of 1,500 square kilometers.

Lafia was the local administrative and economic centre for the region and major north-south rail and road arteries passed through the town. Lafia thus formed a nodal point in Nigeria's communication network. The main road northwards ran close to the western boundary of the project area; while the main road eastwards ran through the Akuni catchment, crossing the Dep river at Sabon Gida, to form the southern boundary of Pandam Wildlife Park.

### 6.1.2 Vegetation and Land Use.

Following on from the comparative study of aerial photographs of the whole LADP area, a more detailed interpretation of the 1972/74 aerial photography of the BICOT project area was carried out and a base map produced. Figure 6.1 shows the extent and distribution of riverine vegetation in 1972/74. In addition, for each of the 35 sub-catchment sectors identified on the base map, the following parameters were determined:

FIGURE 6.1 : BICOT PROJECT AREA



Total sector area.  
Length of riverine forest.  
Mean width of riverine forest.  
Total area of riverine forest.  
Proportions land occupied by:  
    cultivation,  
    uncultivated land,  
    riverine forest,  
    drainage lines,  
    open water,  
    roads and settlements.

The tabulated results of this vegetation and land use analysis are given in appendix 3, but the salient features are summarised in histograms shown in figure 6.2. Considerable sector to sector variation was evident, but sectors typically had 50% to 60% of their area within the cultivation cycle; 30% to 40% was uncultivated; and riverine forest occupied 4% to 5%. It can be seen from figures 6.3 and 6.4 that the highest land use intensities occurred to the south-west in a wide zone around Lafia town, and along the major roads radiating outwards.

Thus, although under Keay's (1953) classification system the natural vegetation of the area should have been of the southern Guinea type, it has been greatly modified by human activity. Relatively little natural southern Guinea vegetation has survived, and the region has been transformed into a mosaic of farmland and wooded grassland, intersected by a dendritic pattern of riverine forest.

This forest vegetation was an unusual feature of the region. Its occurrence was dependent on a large number of perennial springs which rose from outcrops of the Lafia sandstone formation, and resulted in permanent stream flow and moist soil conditions along many drainage lines; the width of riverine forest being determined by the extent of dry season ground seepage, and slope. Original human settlement in the area, and subsequent agricultural expansion, were likely to have been greatly influenced by these perennial water sources.

FIGURE 6.2 : SECTOR VEGETATION AND LAND USE ( HISTOGRAM NUMBERS IDENTIFY SECTORS

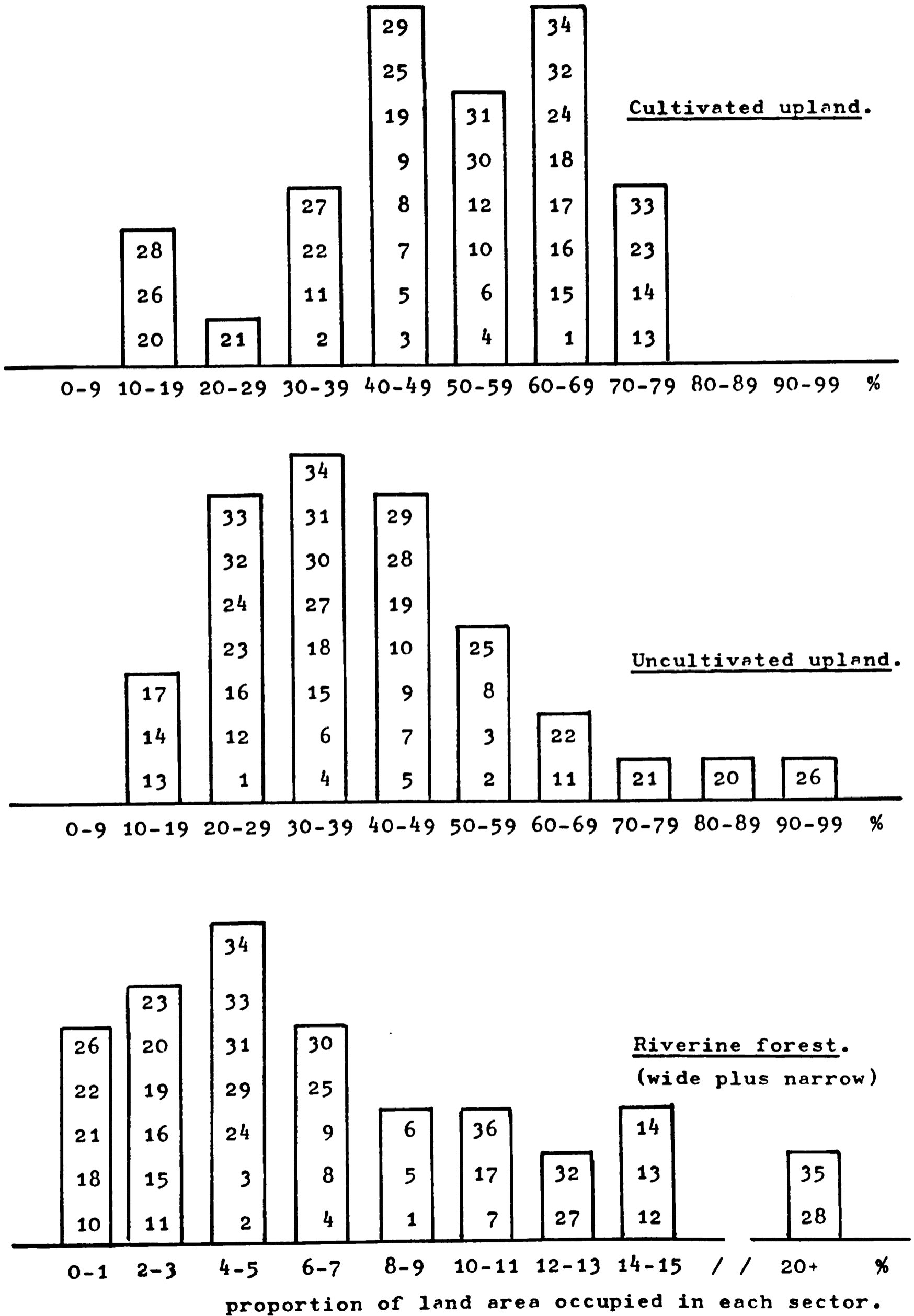
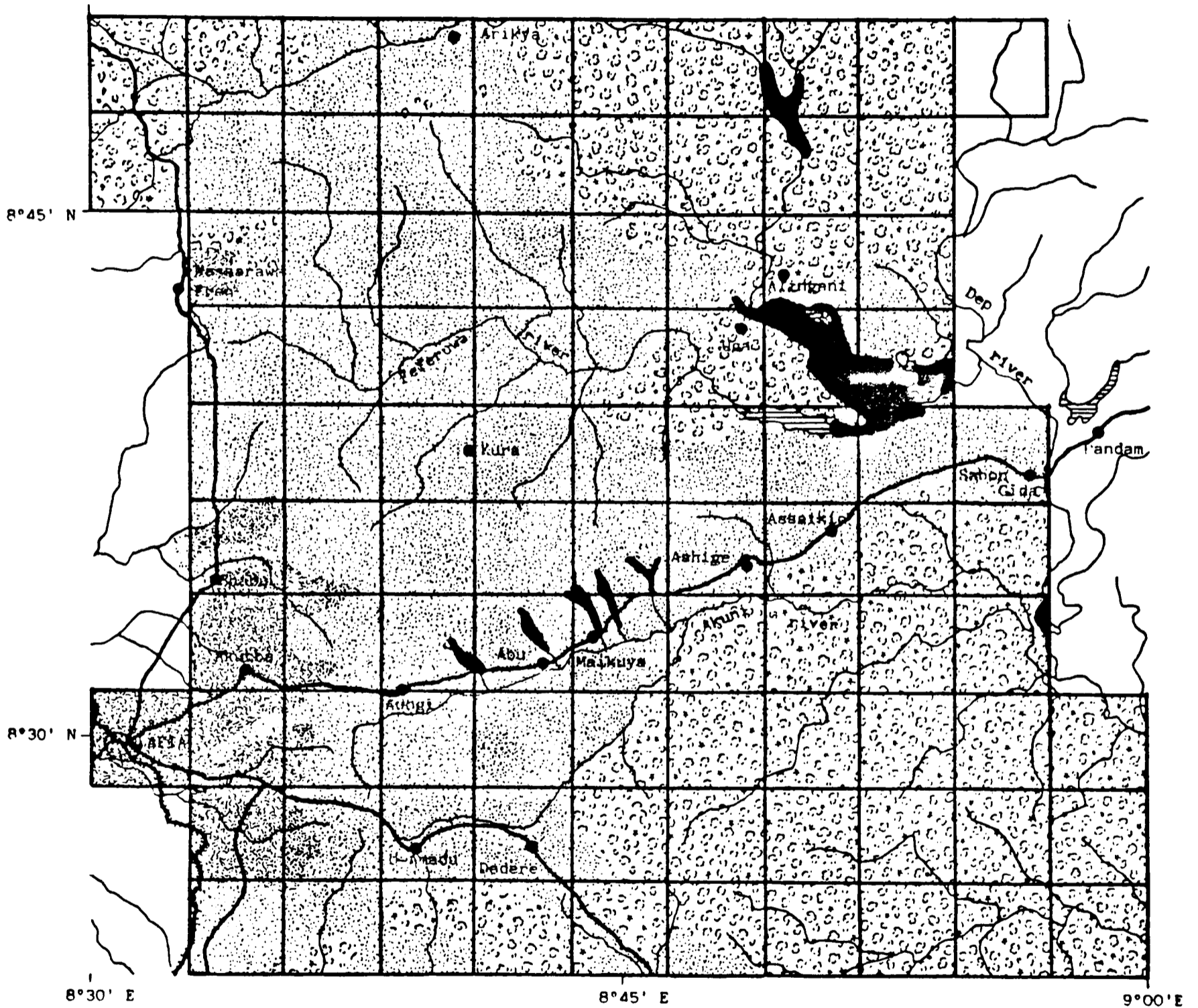


FIGURE 6.3 : VEGETATION AND LAND USE - 1976 SLAR IMAGERY



Each grid 5km x 5km. Approximate scale 1 : 350,000

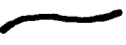

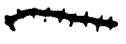





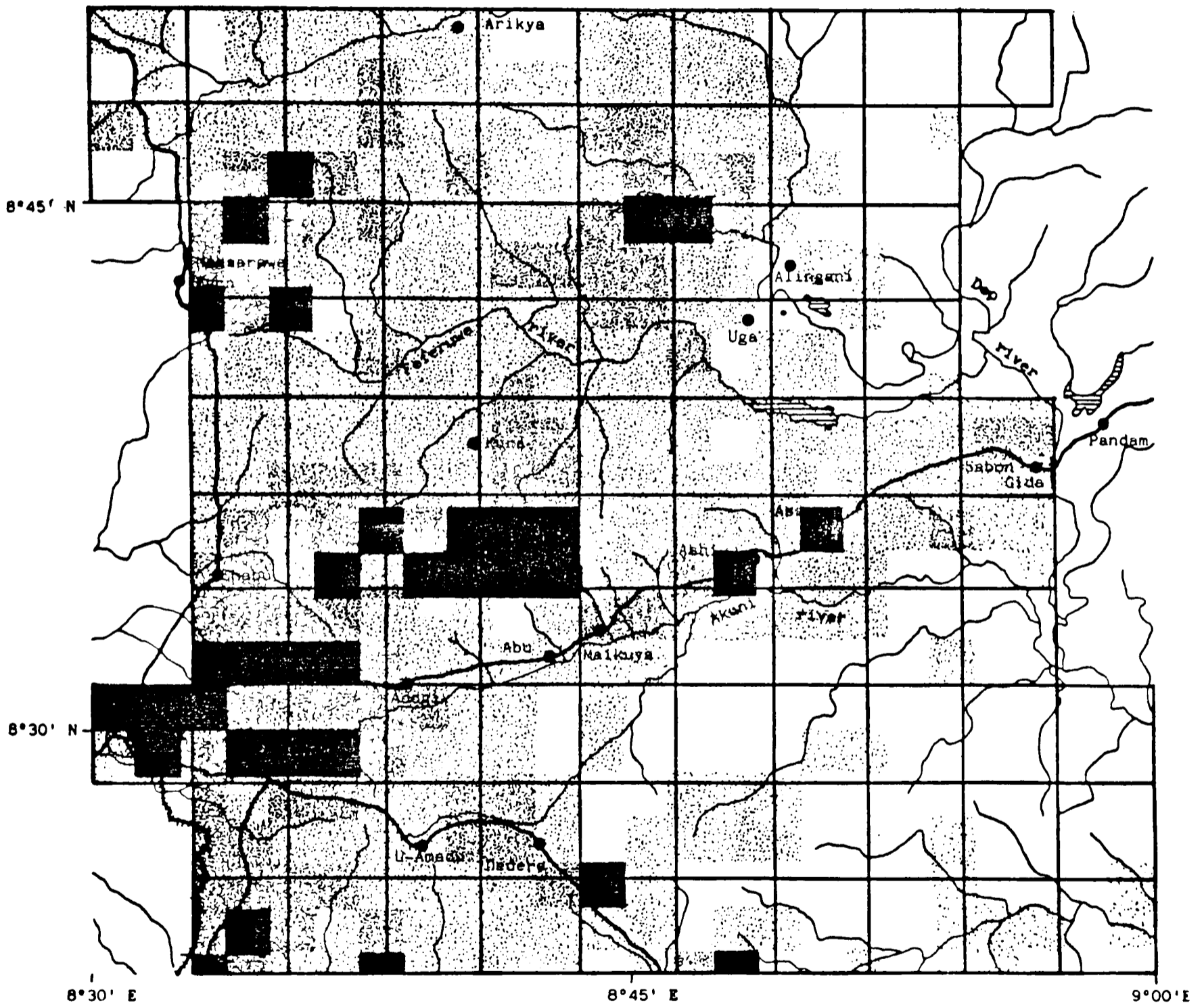


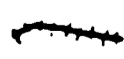





- |   |                     |   |                              |
|---|---------------------|---|------------------------------|
|  | Major roads.        |  | Riverine forest.             |
|  | Railway line.       |  | Wooded shrub grassland.      |
|  | Rivers and streams. |  | Farmland > 60% intensity.    |
|  | Lakes.              |  | Farmland 30 - 60% intensity. |

FIGURE 6.4 : LAND USE INTENSITY - 1972/74 AERIAL PHOTOGRAPHY



Each grid square, 5km x 5km. Approximate scale 1;350,000

- |   |                     |   |                                 |
|---|---------------------|---|---------------------------------|
|  | Major roads.        |  | > 60% within cultivation cycle. |
|  | Railway line.       |  | 35 - 60% " " "                  |
|  | Rivers and streams. |  | 10 - 34% " " "                  |
|  | Lakes.              |  | > 10% " " "                     |

After the vegetation and land use analysis described above had been completed, more recently acquired computer enhanced LANDSAT imagery became available for inspection (LADP, 1981). Although its resolution (about 80 meters) was much inferior to that of aerial photography, evergreen forest vegetation showed up very distinctly on false colour images, and was mapped for comparative purposes (see figure 6.5). There is clearly a very close correspondence in the distribution of riverine forest as revealed by the two forms of imagery. Satellite imagery has considerable potential for the rapid mapping of tsetse habitats over large areas, and could be of great value in future tsetse survey work. (See section 6.4.3.)

### 6.1.3 Climate.

The region experienced a seven month wet season from April to October and had a mean annual rainfall of about 1,200mm (figure 6.6), with July, August and September being the wettest months.

Diurnal temperature ranges were much greater than the annual range of mean monthly temperatures, with the latter ranging from 26°C in September to 30°C in March. Mean monthly maximum temperatures ranged from 30°C to 38°C, with a peak occurring in late February to early March, before the onset of the rains. Mean monthly minimum temperatures ranged from 18°C to 25°C, with lowest temperatures occurring in January and February, (figure 6.7).

FIGURE 6.5 : RIVERINE FOREST - 1976 LANDSAT IMAGERY

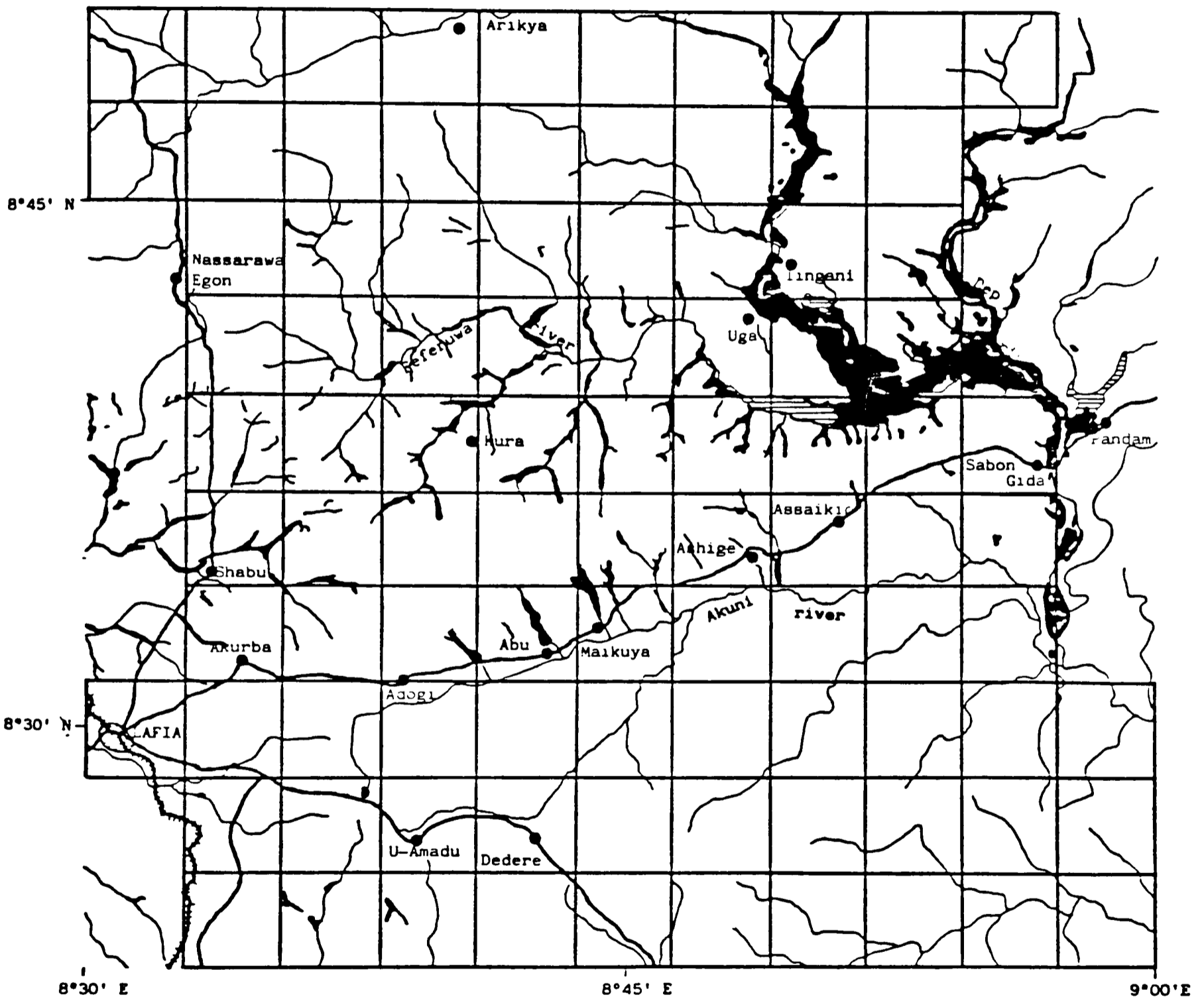


FIGURE 6.6 : MEAN MONTHLY RAINFALL  
(AFTER KOWAL & KNABE, 1972)

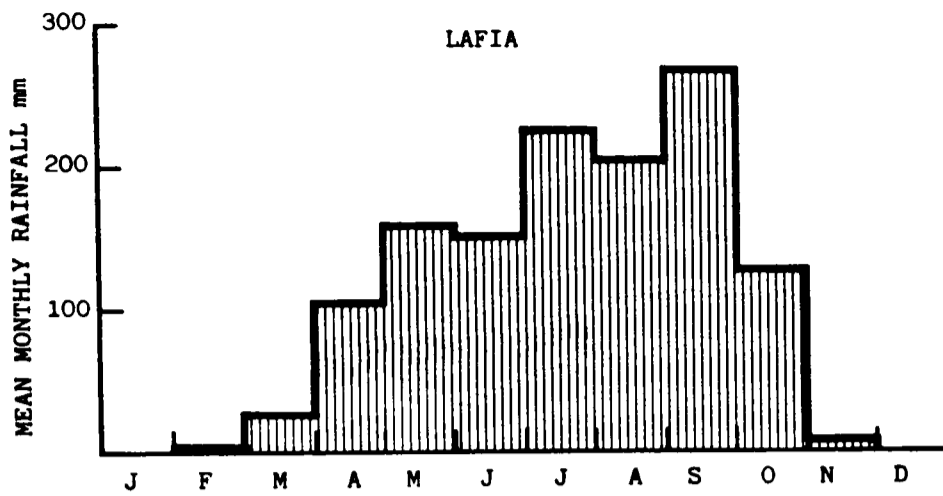


FIGURE 6.7 : MEAN MONTHLY TEMPERATURE  
(AFTER KOWAL & KNABE, 1972)

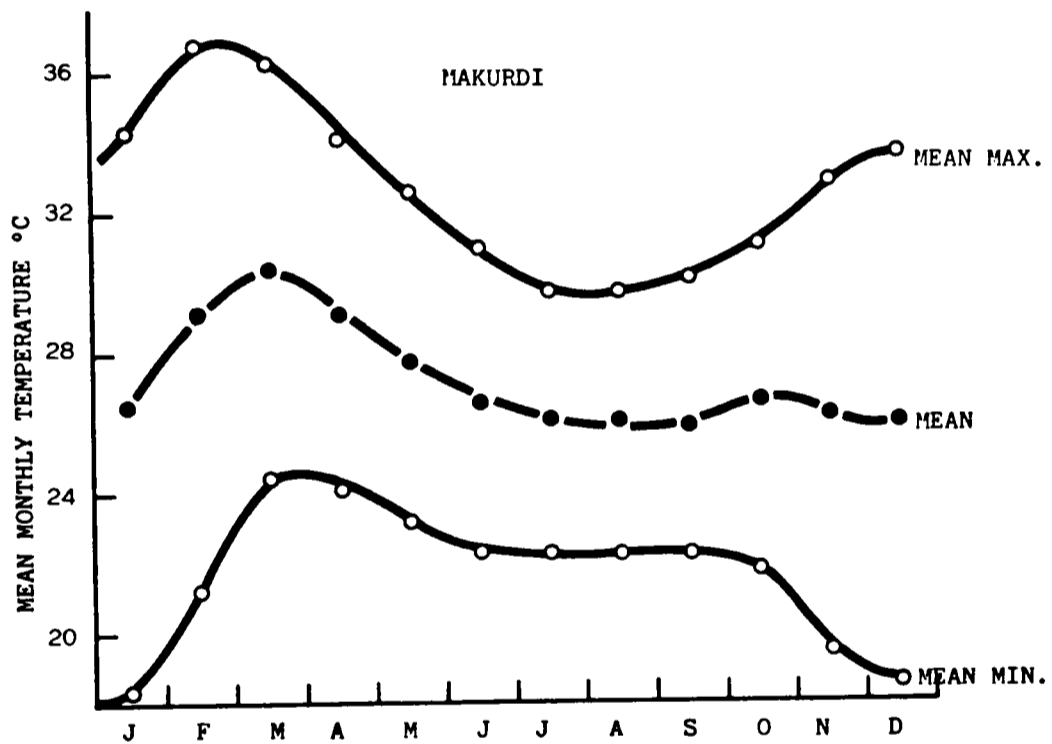
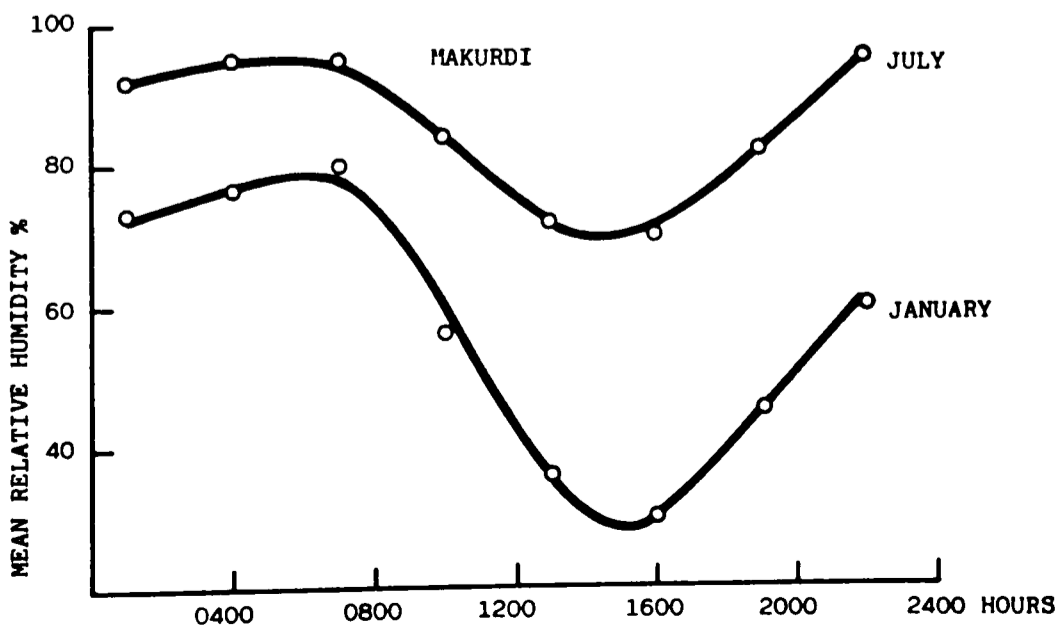


FIGURE 6.8 : MEAN HOURLY RELATIVE HUMIDITY  
(AFTER KOWAL & KNABE, 1972)



The diurnal range in relative humidity was greater than the mean monthly range. In January hourly relative humidity values ranged from 20% at 1600 hours to 80% at 0700 hours; while in July the range was from 70% to 95%, (figure 6.8). Irregularly through the dry season, but with increasing frequency towards its end, brief periods of greater aridity, with relative humidity of less than 10%, occurred during "harmattan" conditions, when dry north-easterly, dust-laden Sahara winds prevailed.

The temperature and humidity values mentioned above were recorded over many years at the nearest synoptic meteorological station at Makurdi (Kowal and Knabe, 1972), to the south of the BICOT project area and indicate conditions typical of an open upland setting. BICOT established its own meteorological station at its field headquarters at Adogi (sector 23), and also began simultaneous recording, with matched pairs of thermohygrographs, of microclimatic conditions within a nearby extensive patch of riverine forest (sector 12). Readings obtained during March, April and May 1982, when climatic conditions were most extreme, clearly illustrated the insulating capacity of evergreen riverine forest habitat. Temperature and humidity in both upland and forest habitats showed diurnal cycles, but amplitudes were much lower in the riverine forest. Figures 6.9 and 6.10 show the degree to which minimum humidity was enhanced, and maximum temperature was suppressed.

Thus it was clear that although extreme maximum upland temperatures on occasion exceeded 40° C, maximum temperature in the forest core was unlikely to exceed 31° C. Similarly under extremely dry harmattan conditions, with relative humidity falling to 10% in the uplands,

FIGURE 6.9 : CLIMATIC INSULATION OF WIDE FOREST HABITAT - HUMIDITY ENHANCEMENT

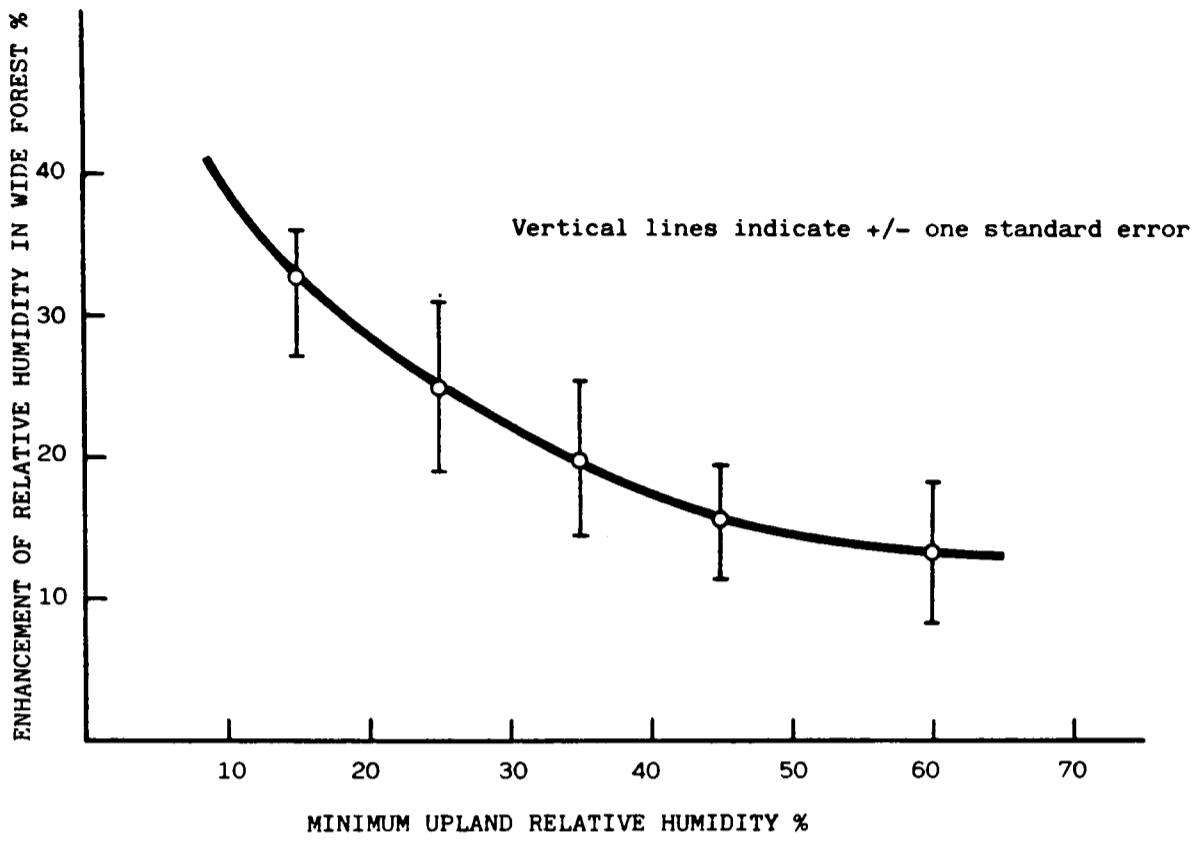
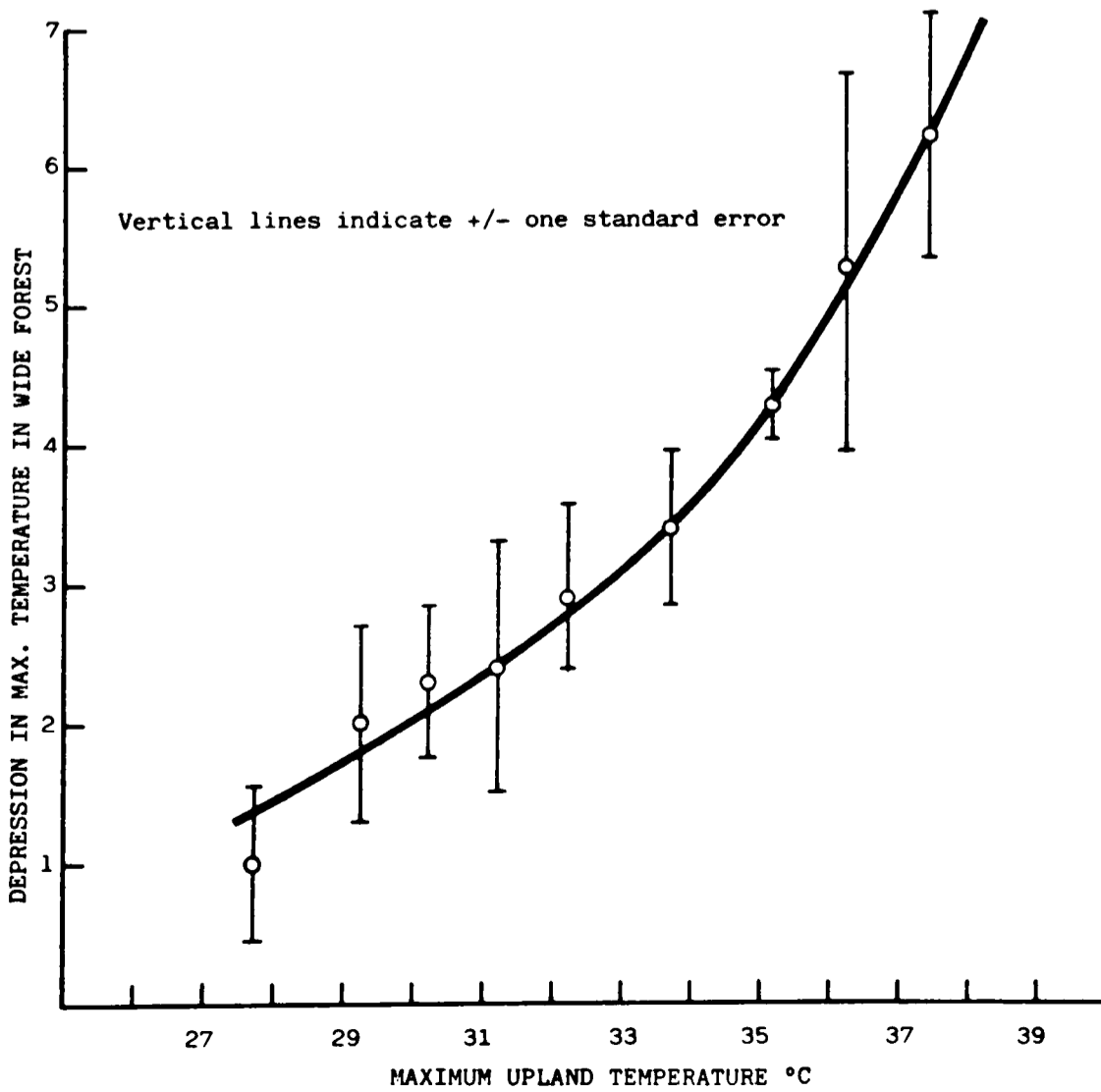


FIGURE 6.10 : CLIMATIC INSULATION OF WIDE FOREST HABITAT - TEMPERATURE DEPRESSION



relative humidity in the forest was unlikely to fall below 50%. However, at the periphery of wide forests, particularly where agricultural and fire encroachment had taken place, the insulating effect would break down.

#### 6.1.4 Human Population.

As mentioned in chapter 5, the human population within the LADP area has significantly increased in size in recent years, both through natural population growth and because there has been a substantial influx of people from north and south. Although, as previously explained, human population estimates were subject to wide margins of error, available information indicated an overall annual rate of increase of about 4% to 5%.

Conservative estimates, based on farm census returns (LADP, 1978), and an assumed average household size of 5 individuals, indicated a total population of around 600,000 for the LADP area. If land use intensity pattern is taken as reflection of human population distribution, then with the generally higher land use intensity in the 2,500 square kilometer BICOT project area, which occupied approximately one quarter of the LADP area, it is not unreasonable to suggest that more than a quarter, and probably nearer a third of the total LADP human population lived within the BICOT project area; say 175,000 to 200,000 people, which was equivalent to 70 to 80 per square kilometer.

### 6.1.5 Agriculture.

The region fell within the transition zone between typically grain growing areas to the north, and root cropping regions further south. Moderately fertile soils, good rainfall and a long growing season allowed a wide variety of crops to be grown. Intercropping, either through relay crops or undersowing was common. Double cropping of short duration crops, and dry season cultivation of moister soils along drainage lines, following deforestation, were also practised. The major food crops were: yams, sorghum and millet, with the first two also being major cash crops (LRDC, 1979a).

Cultivation was mainly by hand. Draught animals were rarely used and the extent of mechanised cultivation was very limited. Land was usually cropped for six to seven years, followed by five to ten years of bush fallow, although this ratio has almost certainly declined. Some field manuring took place during crop residue consumption by cattle, but the use of artificial fertilizers, supplied by LADP, has increased.

Most cattle were owned by Fulani, many of whom had recently settled, permanently or semi-permanently, in the area (see appendix 4). The distribution and abundance of cattle are considered in greater detail in chapter 7; suffice it to mention at this point, that the dry season cattle population within the BICOT project area was estimated by low level aerial survey to be 38,000 head, equivalent to 16 animals per square kilometer.

Smaller numbers of other livestock, including sheep, goats and pigs were also kept, most of which were owned by arable farmers.

## 6.2 Tsetse Sampling.

Nigerian tsetse survey and population monitoring work has in the past largely depended on "tsetse patrols" and "fly rounds", in which groups of two or three men walked through selected areas, with or without bait animals, stopping periodically to catch tsetse with hand nets, (Davies, 1977). The method is labour intensive, time consuming and arduous; and the results are very much dependent on the experience, reliability and conscientiousness of the individuals concerned.

An alternative and inherently more reliable, standardised method of sampling tsetse populations is by use of blue biconical "Challier" traps (Challier and Laveissiere, 1973; Ryan and Molyneux, 1980), which have recently gained widespread acceptance in West Africa. The efficacy of the trap depends on initial attraction of tsetse by its shape and colour; once in the immediate vicinity of the trap, the provision of darkened refuges at its base induce tsetse to enter; subsequent phototropic escape responses cause them to move upwards into an apical collection cage. (When Kock & Spielberger (1979) and Davies (1977) commented that biconical traps were relatively ineffective, they were referring to an inaccurate copy of an early design of trap.)

### 6.2.1 Surveying.

During the course of preparatory field work by BICOT, prior to the release of sterile males, tsetse surveys were carried out throughout the 2,500 square kilometer project area, using biconical traps.

Essentially the survey method consisted of four stages:

The first stage involved the identification of suitable habitats and ground reconnaissance, using 1:100,000 and 1:50,000 scale Federal Department of Surveys maps (sheets: 210, 211, 231 and 232), which were based on early 1960 aerial photography. The more recent 1972/74 aerial photographs were also used.

Having accurately determined ground location, the second stage involved making access into, through or around the usually dense undergrowth of the riverine forest vegetation, and selecting suitable trapping sites at approximately 250 meter intervals. Sites were chosen on the basis of the "best" available at the required spacing. "Best" was a subjective judgement based on previous experience of sites with high catches, and usually involved a compromise between the following considerations: good trap visibility; well sunlit position; and proximity to water or an imagined tsetse flight path.

The third stage involved setting traps, identifying and marking their position by painting a number on the nearest convenient tree, and recording a brief description of the general habitat, and each trap site. Depending on the size of the habitat, between five and 50 traps were deployed.

In the final sample collection stage, traps were visited on the morning after setting and the top cages containing tsetse were removed. They were replaced with fresh cages and the previous day's catch was transported in cool boxes for examination at base camp. On the following morning, the second day's catch was collected, and at that time the traps themselves were usually also removed.

### 6.2.2 Monitoring.

During tsetse population monitoring, a similar sampling technique to that described above for surveying was employed, but the trapping period was often extended. In addition an automated, electrified biconical trap (Ryan et al., 1981) was also occasionally used.

### 6.2.3 Information Collected.

From the outset, records of the following parameters were kept: trapping dates; sub-catchment sector and trap reference numbers; times of setting and collection; habitat and trap site descriptions; and the number and sex of each species caught in each trap, each day. Subsequently during later stages of tsetse survey and population monitoring studies, additional qualitative information was recorded for each individual tsetse caught: teneral or non-teneral status, wing fray, and, if female, ovarian stage and uterine content.

### 6.3 Biconical Trap Catch Characteristics.

During the course of two years field work, carried out between March 1980 and March 1982, a total of 28,755 tsetse were caught within the BICOT project area from 1,457 trap sites, over 5,185 trapping days. Three species were found. G. palpalis was the most commonly caught, representing 91.5% of the total catch (58% female); G. tachinoides accounted for 7.7% (50% female) and G. longipalpis made up the remaining 0.8% (40% female). Table 6.1 gives a breakdown of the total catch.

#### 6.3.1 Influencing Factors.

Before examining the results in more detail, it is pertinent to consider some of the major factors liable to influence tsetse samples obtained by biconical traps.

TABLE 6.1 BREAKDOWN OF TSETSE CAUGHT WITHIN THE BICOT PROJECT AREA, USING BICONICAL TRAPS, DURING THE PERIOD MARCH 1980 TO MARCH 1982.

Trapping Sites	Days	NUMBER CAUGHT										RELATIVE ABUNDANCE*									
		G. palpalis			G. longipalpis			G. tachinoides			G. palpalis			G. tachinoides			G. longipalpis				
		Males	Females	Sum	Males	Females	Sum	Males	Females	Sum	Males	Females	Sum	Males	Females	Sum	Males	Females	Sum		
<u>TOTAL CATCH</u>		1457	5185	11031	15289	26320	1107	1095	2202	141	92	233	2.13	2.95	5.08	0.21	0.21	0.42	0.03	0.02	0.04
<u>WIDE FOREST</u> - first two days trap catch only.																					
M to N	329	658	2151	3024	5175	108	171	279	0	0	0	3.27	4.60	7.86	0.16	0.26	0.42	0.00	0.00	0.00	
D to A	531	1062	2567	3031	5598	360	254	614	124	84	208	2.42	2.85	5.27	0.34	0.24	0.58	0.12	0.08	0.20	
J to D	860	1720	4718	6055	10773	468	425	893	124	84	208	2.74	3.52	6.26	0.27	0.25	0.52	0.07	0.05	0.12	
<u>NARROW FOREST</u> - first two days trap catch only.																					
M to N	106	212	24	40	64	45	31	76	0	0	0	0.11	0.19	0.30	0.21	0.15	0.36	0.00	0.00	0.00	
D to A	251	502	112	124	236	142	139	281	7	4	11	0.22	0.25	0.47	0.28	0.28	0.56	0.01	0.01	0.02	
J to D	357	714	136	164	300	187	170	357	7	4	11	0.19	0.23	0.42	0.26	0.24	0.50	0.01	0.01	0.02	

\* Flies per trap per day. M to N = May to November. D to A = December to April. J to D = January to December.

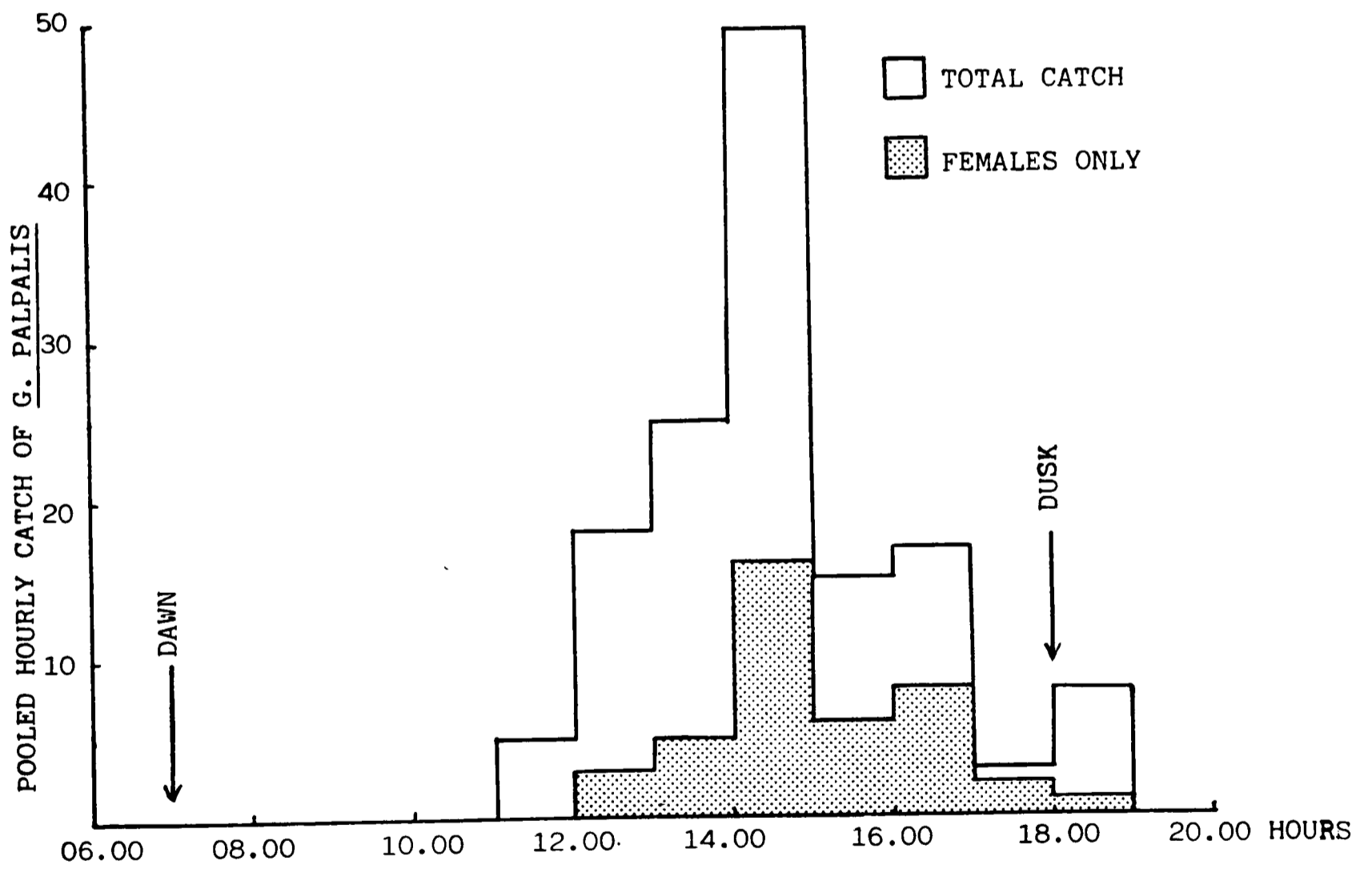
Factors influencing trap attractiveness included its colour, shape and general visibility. Shape and colour were constant, while trap visibility varied with position, lighting, season and habitat. Once attracted to the immediate vicinity of a trap, the number of flies caught depended on the capture efficiency of the trap, and the duration of trapping.

Tsetse related factors include the degree to which a particular species, or sex of tsetse is attracted to the trap; species abundance; and flight activity. The latter depended on the stage within the diurnal, feeding and reproductive cycles; and climatic factors such as temperature and humidity.

### 6.3.2 Diurnal Cycle.

Tsetse catches from immobile biconical traps are related to the activity of the the individuals caught. The diurnal activity pattern is shown in the histogram of hourly catches of G. palpalis in figure 6.11, which was obtained from a single automatic trap situated in the extensive Dep-Gwayaka forest (sector 35), operating over a five day period in the middle of the dry season (January). Under the prevailing conditions, the hourly catch distribution was unimodal, peaking at between 1400 and 1500 hours. The minor peak that occurred between 1800 and 1900 hours was probably the result of delayed escape reactions of flies entering the trap in the late afternoon, when the light was fading.

FIGURE 6.11 : POOLED HOURLY CATCH OF G. PALPALIS FROM AUTOMATIC BICONICAL TRAP, OVER A 5-DAY PERIOD IN JANUARY



### 6.3.3 Feeding Cycle.

Recently fed, engorged tsetse were not caught by biconical traps. From analyses of fat and haematin content of G.palpalis gambiensis in the Ivory Coast, Rogers and Randolph (1982) have demonstrated a progressive increase in the proportion of hungrier flies in biconical trap samples, which indicated that better fed flies were less available for capture.

### 6.3.4 Reproductive Cycle.

In large samples of tsetse caught by biconical traps, females with mature larvae in their uteri typically represented a very low proportion of the total catch. For example: out of 376 parous females caught in the extensive Ehula forest (sector 7) during the early dry season, the uterine content of 45% were in the egg stage; 40% contained immature larvae; 9% mature larvae; and 6% had empty uteri. This indicated an undersampling of that proportion of the population carrying heavy, mature larvae, which were relatively inactive, and thus less available for trapping.

### 6.3.5 Hourly Catch and Temperature.

The relationship between hourly catch and temperature, under the circumstances described in 6.3.2, is shown in figure 6.12. Over the somewhat limited range between 16°C and 26°C hourly catch increased progressively. At higher temperatures, hourly catches could be expected to plateau and tail off. Temperature was recorded by a thermohygrograph within a Stephenson's screen placed in a shaded



position five meters from the automatic trap. (Relative humidity within the forest was high throughout the period of observation, and no clear catch response could be demonstrated.)

#### 6.3.6 Daily Catch and Maximum Temperature.

Under the conditions described in 6.3.2 total daily catch was found to be related to maximum daily temperature - see figure 6.13. However, it must be emphasised that these observations took place during an exceptionally cool period, when harmattan conditions briefly coincided with the time of lowest mean monthly minimum temperatures. This resulted in unusually low daily maxima. As has been discussed in section 6.1.3 maximum daily temperatures within wide forest habitats during the dry season were usually higher, and normally peaked around 30°C to 31°C.

#### 6.3.7 Effects of Prolonged Trapping on Daily Catch.

Prolonged periods of trapping by many traps, in relatively limited habitats, resulted in marked reductions in the number of G. palpalis caught each day (see figure 6.14). Changes in the qualitative composition of the daily catch were also apparent. Mean age, as determined by wing fray and ovarian ageing techniques (Saunders and Phelps, 1970; Baldry and van der Vloedt, 1982), declined and the proportion of teneral flies increased (see figures 6.15 and 6.16) . These quantitative and qualitative changes in daily catch indicated that the removal of individuals during prolonged trapping significantly altered the size and composition of the tsetse population at large, and that traps thus had a catching out effect.

FIGURE 6.14 : PERCENTAGE REDUCTION IN DAILY CATCH DURING CONTINUOUS TRAPPING

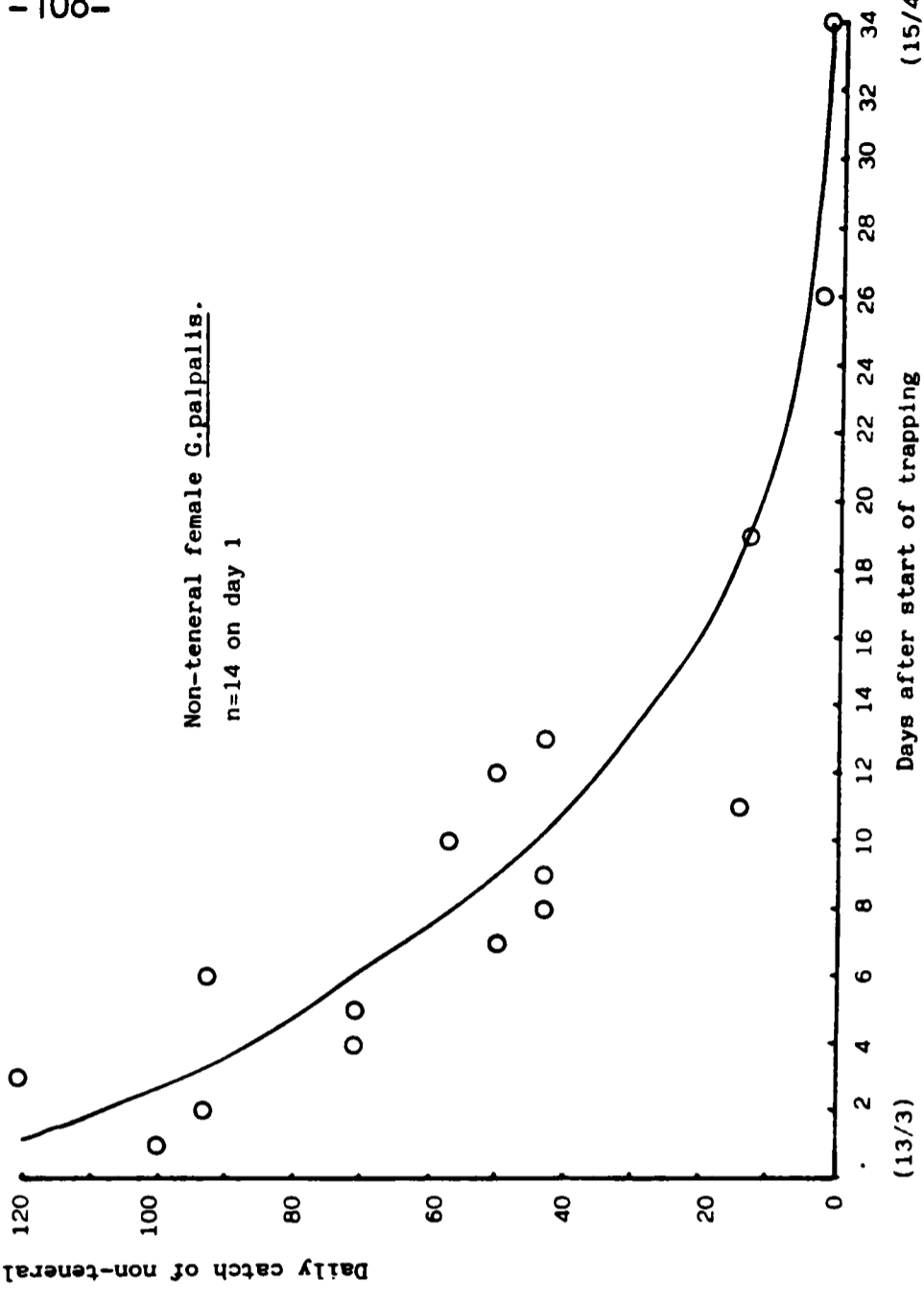
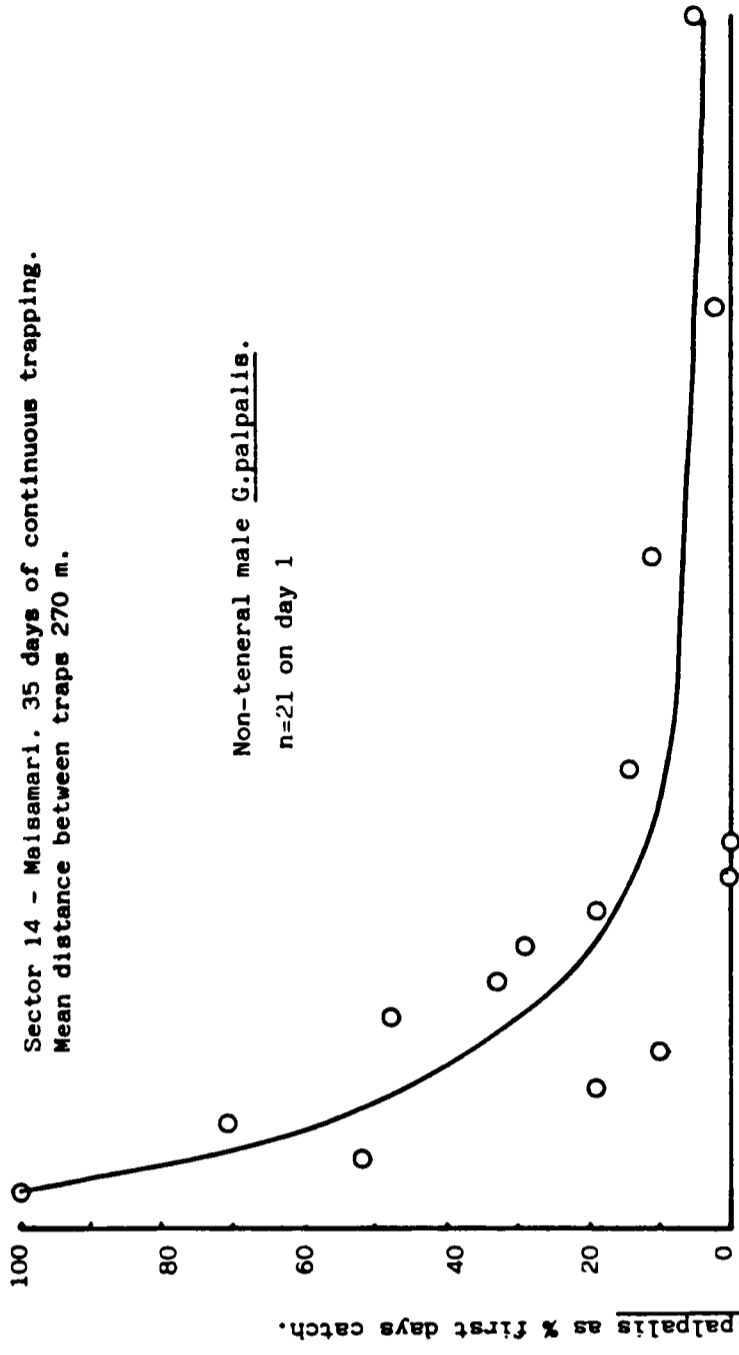
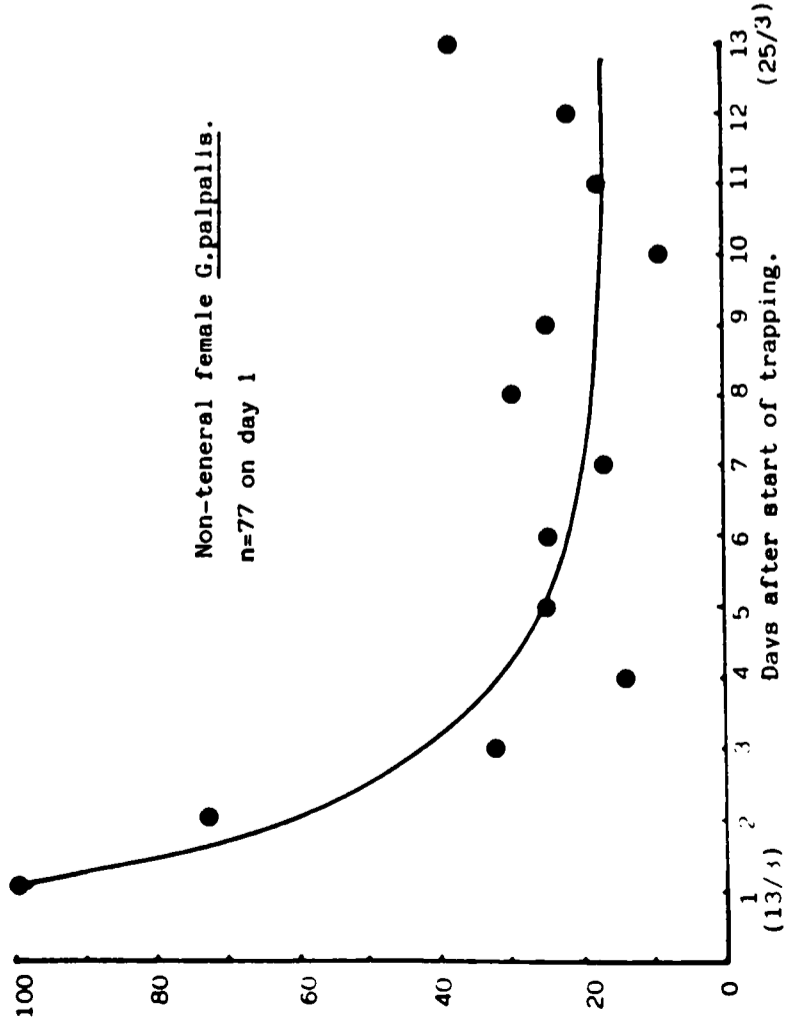
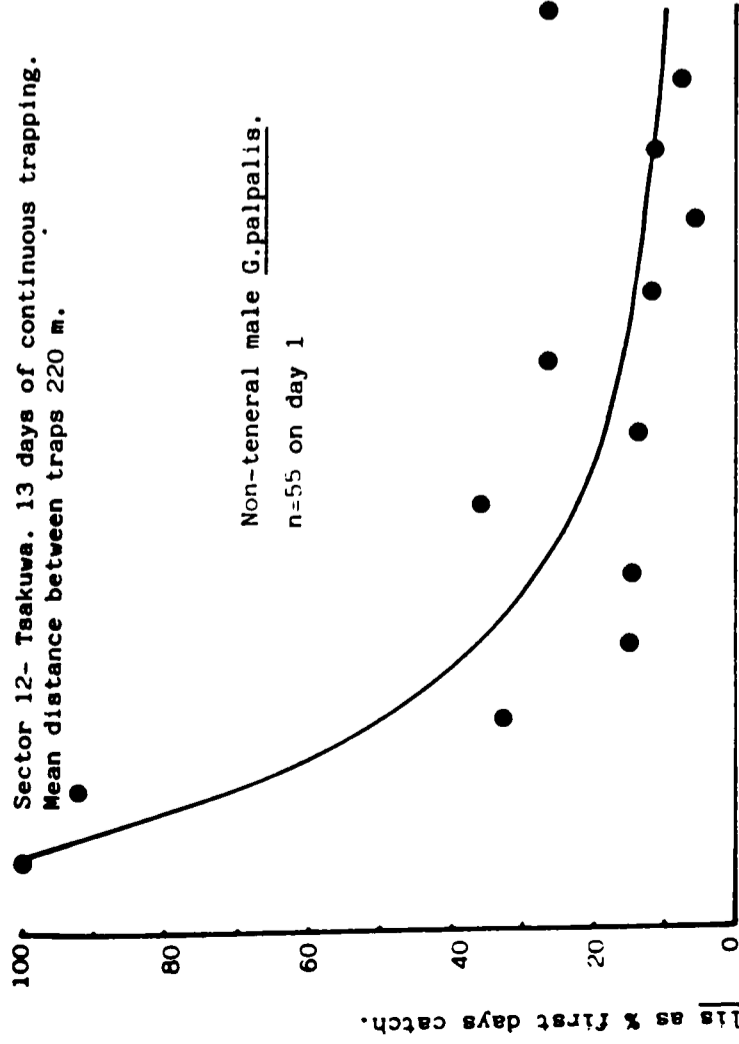


FIGURE 6.15 : CHANGES IN MALE WING FRAY STRUCTURE OF  
G. PALPALIS CATCH DURING CONTINUOUS TRAPPING

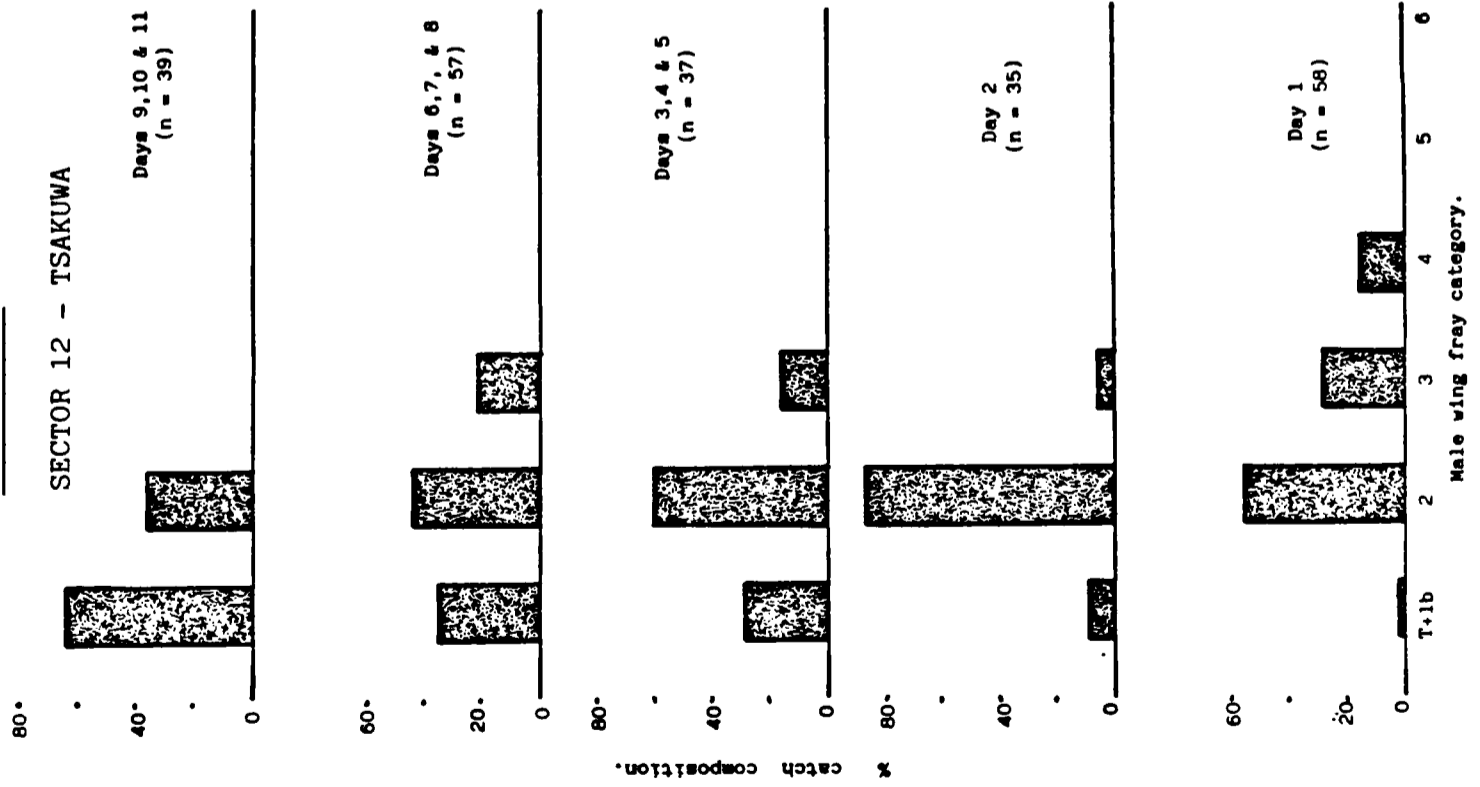
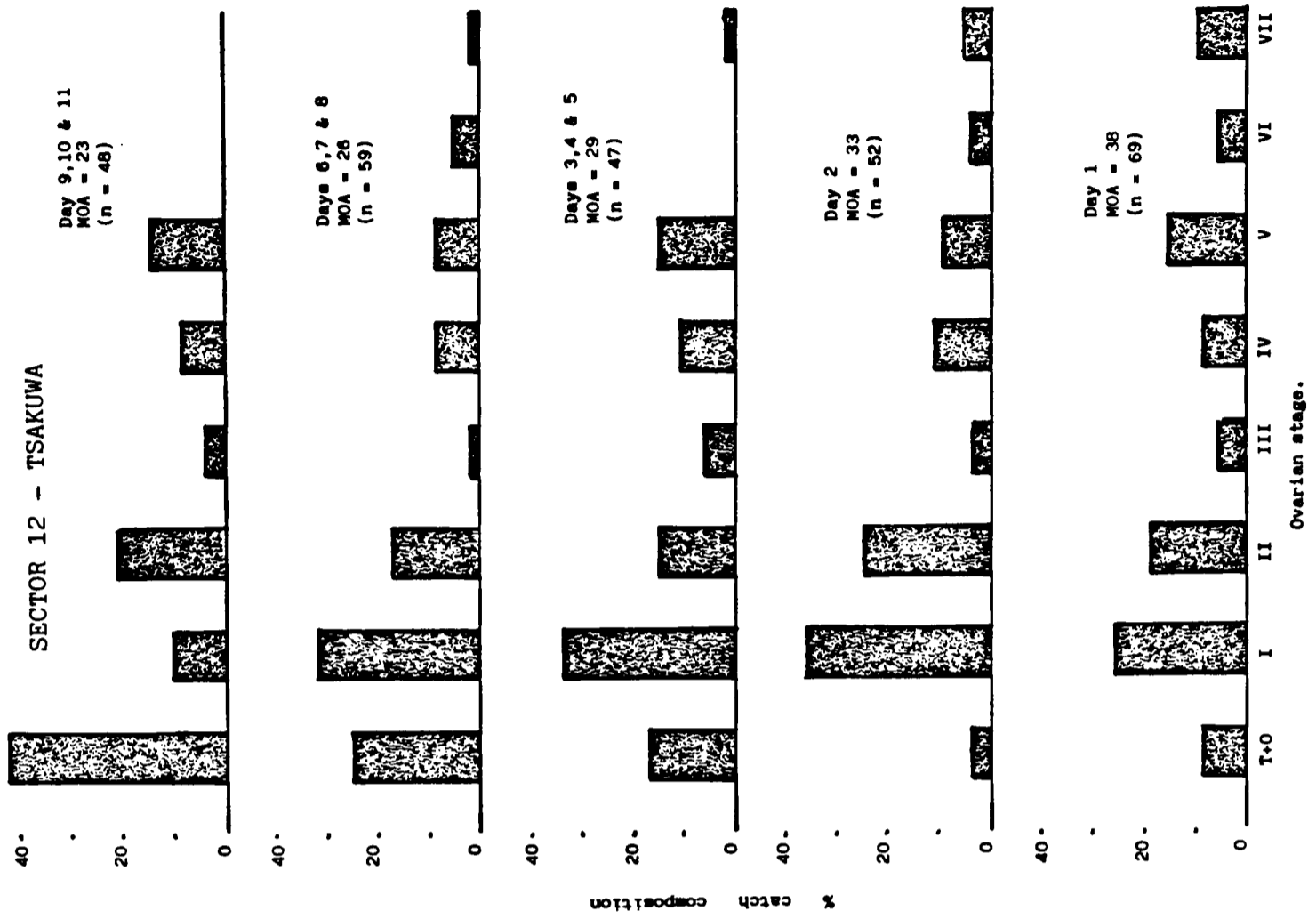


FIGURE 6.16 : CHANGES IN OVARIAN AGE STRUCTURE OF  
G. PALPALIS CATCH DURING CONTINUOUS TRAPPING



### 6.3.8 Recapture Rates.

A further indication of the ability of biconical traps to catch a high proportion of the available population was obtained during G. palpalis mark-release-recapture studies, described in section 6.5, in which recapture rates were usually in the order of 20% to 30%.

### 6.3.9 Relative Abundance.

The standard measure of relative abundance adopted during tsetse surveys of the various sectors within the BICOT project area was the mean number of individuals of a given species (males, females, teneral and non-teneral inclusive), caught over the first two trapping days, by a string of traps spaced at approximately 250 meter intervals.

## 6.4 Tsetse Distribution

### 6.4.1 Species Present and Overall Distribution.

No G. morsitans were found within the BICOT project area, although elsewhere in Nigeria (Yankari Game Reserve) identical biconical traps have been demonstrated to be capable of catching substantial numbers of this species. (Dransfield et al, 1982). Given the intensity and duration of the trapping survey, it seems reasonable to conclude that G. morsitans no longer occurs in the area, and that the extent of belt 42, as shown on the current national tsetse distribution map, has greatly contracted.

The same map indicates that specimens of G. longipalpis have in the past been collected from a number of different localities within the project area (see also Glover, 1965). Page (1959a) has described the ecology of this species in southern Nigeria. During BICOT's recent extensive tsetse survey work, catches of G. longipalpis were confined exclusively to the forests of Pandam Wildlife Park and its immediate vicinity (sector 35).

In marked contrast to G. longipalpis, the two riverine species, G. palpalis and G. tachinoides, were encountered in virtually every sector surveyed. However, their actual distribution was very limited, being closely associated with that of riverine vegetation, which occupied less than 5% of the land area.

Nash and Page (1953) and Page (1959b) have described the typical ecology of G. palpalis in northern and southern Nigeria, while Baldry (1969a) has described variations in the ecology of Glossina species in Nigeria, with particular reference to G. tachinoides.

Prolonged trapping in and around villages, in cultivated areas, and in upland woodland failed to detect appreciable numbers of tsetse, even during the wet season when climatic conditions should have been conducive for dispersal away from riverine habitats. For example, some 400 trapping days spent at 110 trap sites yielded a total catch of 28 G. palpalis and eight G. tachinoides, the majority being caught in cultivated areas within sight of riverine forest.

Tsetse survey work was carried out in the various sectors of the project area during different months of the year. The overall results from each of the two major habitats recognised (wide and narrow

riverine forest) are shown in table 6.1. The results are based on the first two days catch of the trap survey of each sector, and have been divided into the two major seasons: dry months from December to April, with mean monthly maximum temperatures in excess of 30°C; and wet months from May to November, with mean monthly maximum temperatures below 30°C.

The relative abundance of G. palpalis in both wet and dry seasons was much greater in wide forest habitat than in narrow fringing forest - by a factor of between x10 and x25.

The relative abundance of G. tachinoides did not appear to vary greatly, neither with season, nor with habitat type.

The relative abundance of G. palpalis in narrow forest habitats was similar to that of G. tachinoides.

Comparison of seasonal relative abundance is problematic because of the various factors, not only related to the number of flies present, which may influence trap catches. For instance, the increases in relative abundance for both sexes and species, between wet and dry season in narrow forest habitats might be explained by: increased flight activity at higher temperatures; increased trap visibility resulting from defoliation; real increases in population size, which seems unlikely under more extreme climatic conditions; or by a stable, or even decreasing population being concentrated in more restricted habitats. If any of these explanations were true, how can the decrease in G. palpalis relative abundance that occurred between wet and dry seasons in wide forest be explained ?

Given these uncertainties, further analysis of tsetse distribution has been restricted to the results obtained during the dry months from December to April, when mean monthly maximum temperatures exceeded 30° C, and the bulk of the tsetse survey work was in fact carried out.

#### 6.4.2 Relative Abundance by Sector.

During dry season tsetse surveys, sample tsetse catches were obtained from 27 of the 35 sectors within the project area. The relative abundance of the species caught in each sector is given in the frequency histograms shown in figure 6.17. The extent of wide forest habitat in each sector is indicated by intensity of stipple. It is apparent that the relative abundance of G. palpalis was greater in the sectors with larger areas of forest.

No similar trend could be discerned for G. tachinoides, although as indicated by hatching, relative abundance of this species seemed to be greater in southern and western sectors of the project area, where intensity of cultivation was higher, and the degree of human disturbance of riverine forest habitat was more severe.

#### 6.4.3 Relative Abundance and Extent of Forest Habitat.

Dry season relative abundance of G. palpalis in each sector surveyed was plotted against the extent of wide forest habitat and is shown in figure 6.18. The scatter of points is fairly wide, particularly at higher relative abundance values, but the trend for relative abundance to increase in sectors with increasing size of wide forest habitat is clear. Plotted on arithmetic scales (upper graph), a sigmoid curve can be fitted to the points. When relative abundance is plotted on a

FIGURE 6.17 : TSETSE RELATIVE ABUNDANCE BY SECTOR  
( HISTOGRAM NUMBERS IDENTIFY SECTOR)

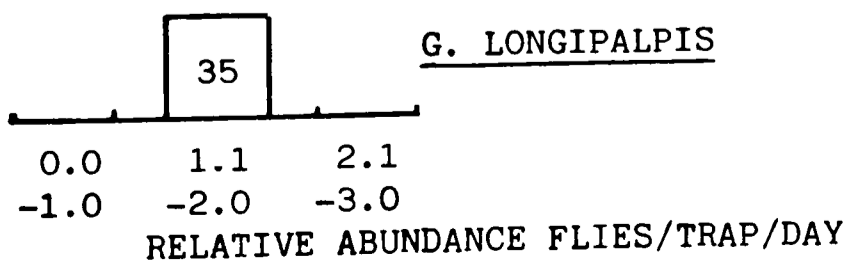
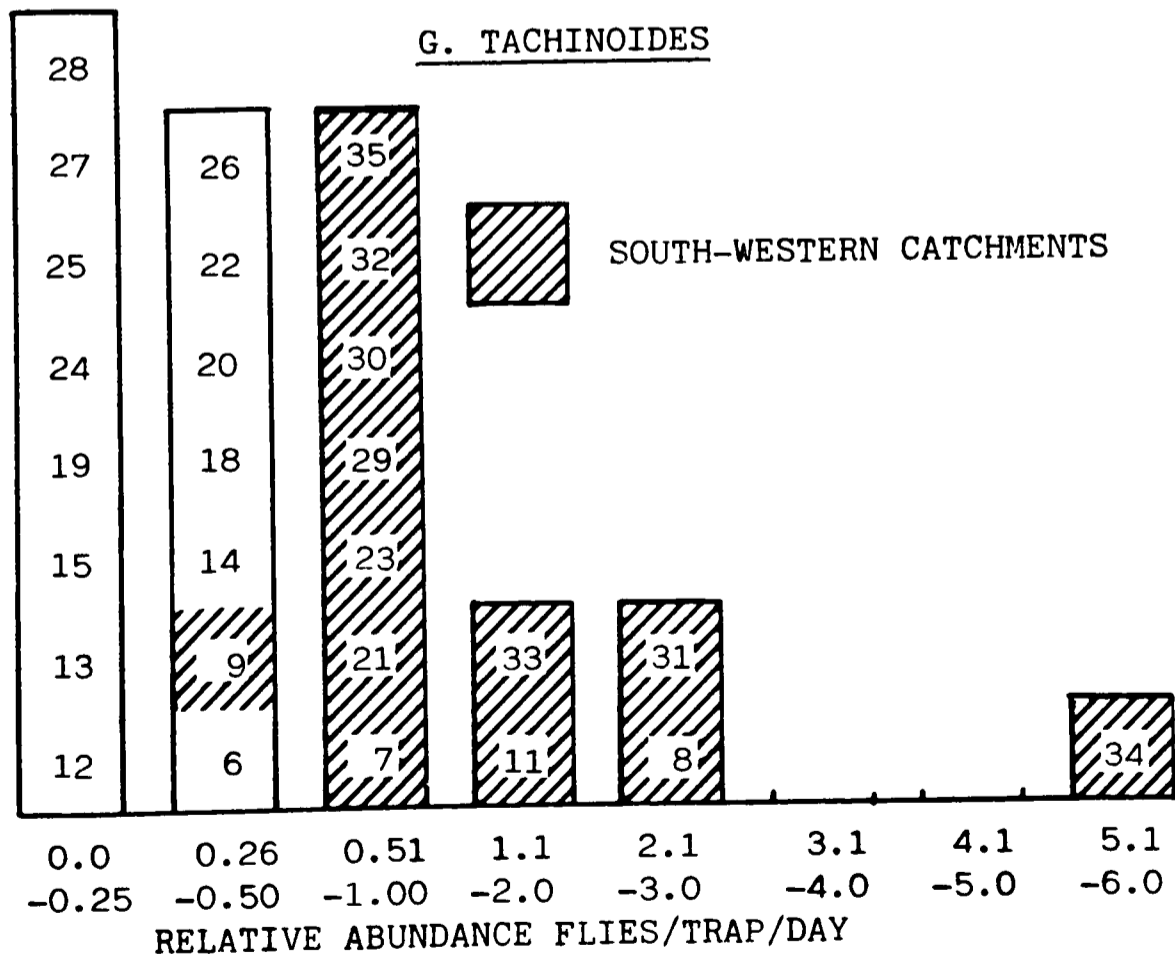
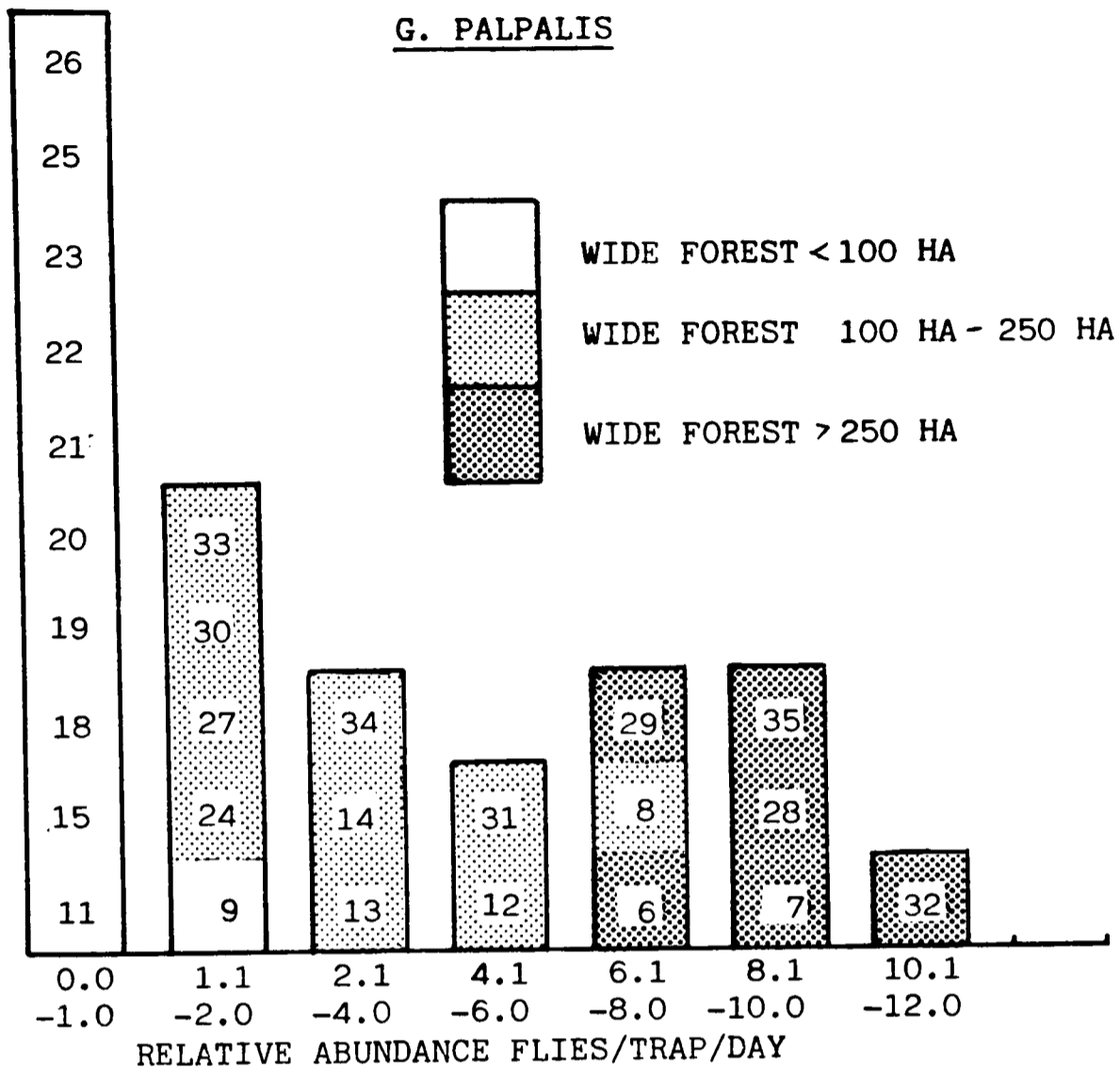
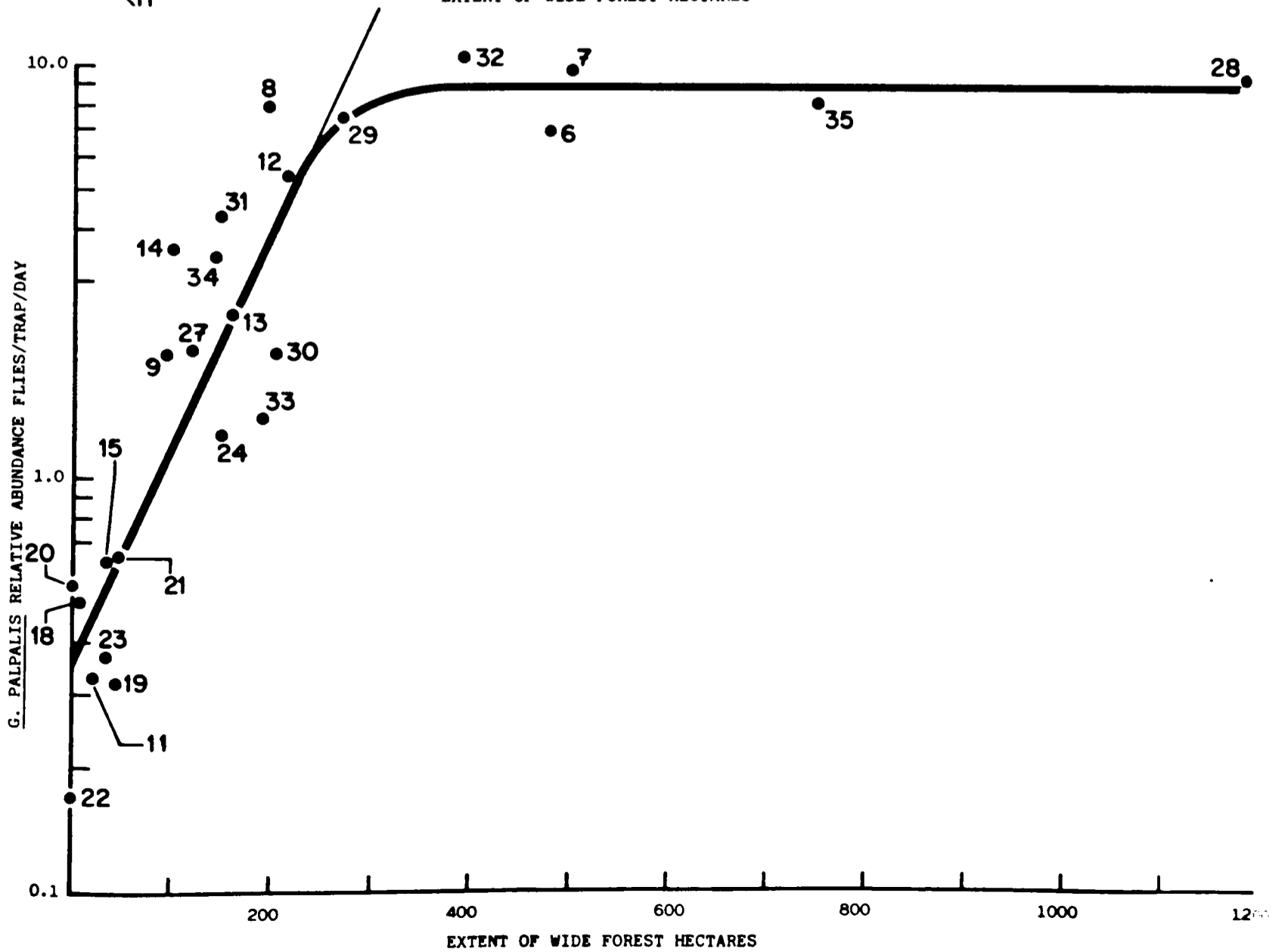
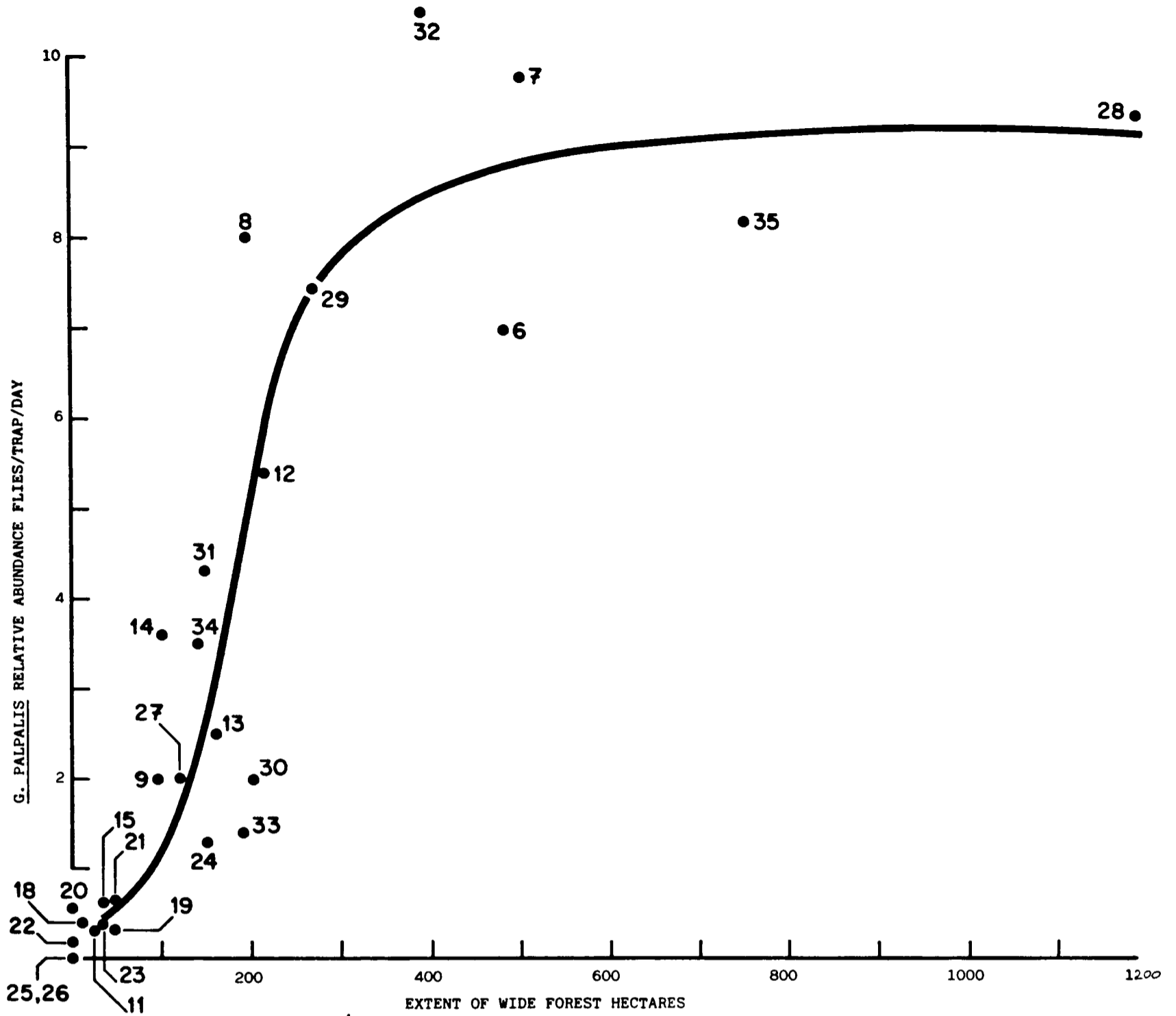


FIGURE 6.18 : DRY SEASON RELATIVE ABUNDANCE OF G. PALPALIS AND EXTENT OF WIDE FOREST



logarithmic scale (lower graph), a straight line can be fitted for those sectors with upto 300 hectares of wide forest habitats.

Only five sectors had forest habitats in excess of that, and the relative abundance of G. palpalis within them was consistently high, between 7 and 11 flies per trap per day. For the majority of sectors however, the linear relationship between relative abundance and the extent of wide forest habitat was defined by the equation:

$$\begin{aligned} \text{Log } y &= 0.00535 x - 0.456 \\ \text{where } y &= \text{relative abundance} \\ \text{and } x &= \text{extent of wide forest} \end{aligned}$$

This equation thus enables predictions of relative abundance to be made from the size of wide forest habitat. The latter can easily be determined from aerial photographs, or even satellite imagery. This relationship thus offers the possibility of rapid preliminary assessment of G. palpalis relative abundance over large land areas within the same ecoclimatic zone, and could be a valuable tool for land use planning and implementation of livestock development and tsetse control projects.

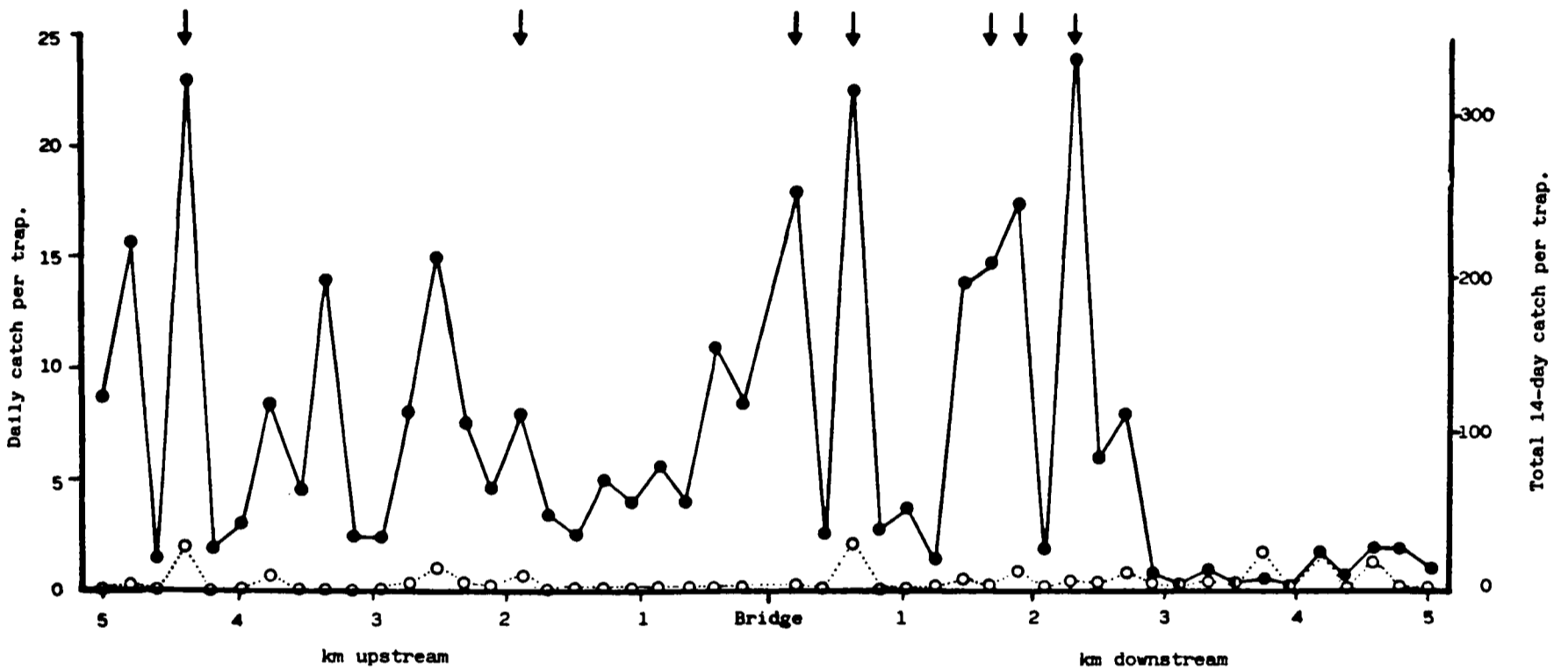
#### 6.4.4 Distribution within Riverine Forest Habitat.

Tsetse catches varied considerably from trap to trap within any given habitat. Examples for both wide and narrow forests are given in figure 6.19, in which the total catch of each trap in a series of approximately equally spaced traps is shown. Highest catches were almost invariably obtained by traps situated at crossing and watering points frequently used by cattle and/or people. Catches from these points were often an order of magnitude greater than catches from traps elsewhere within the same habitat. Both Nash and Page (1953) and

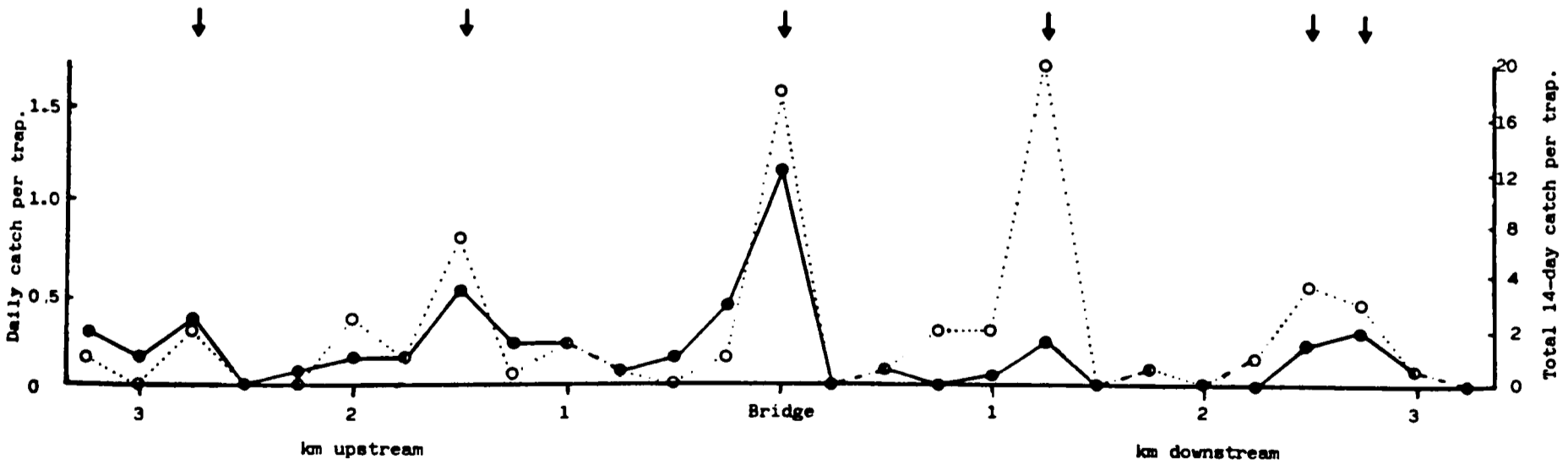
FIGURE 6.19 : TOTAL TSETSE CATCH FROM INDIVIDUAL BICONICAL TRAPS, SPACED AT APPROXIMATELY 250 METER INTERVALS ALONG WIDE AND NARROW RIVERINE FOREST HABITATS, AND TRAPPING CONTINUOUSLY OVER 14 DAY PERIODS.

●—● G. palpalis      ○.....○ G. tachinoides      ↓ Major crossing and watering points.

EHULA WIDE FOREST, SECTOR 7, EARLY DRY SEASON.



AKUNI NARROW FOREST, SECTOR 17 + 18, MID WET SEASON.



Page (1959b) have noted the high catches obtained from conventional fly rounds at, or close to, sites where a trade route or village path crossed riverine vegetation. In the virtual absence of wildlife in the area, these local concentrations of both G. palpalis and G. tachinoides strongly suggest that livestock and people were major, and probably the most important hosts. Casual observations at crossing and watering points, confirmed that both species took blood meals from cattle and man.

#### 6.5 Tsetse Abundance.

In the previous section, tsetse distribution was assessed in terms of the average number of individuals of a given species caught per trap per day, which was used as a measure of relative abundance. It was demonstrated, for example, that the number of G. palpalis caught per trap per day was substantially and consistently higher in wide forests compared with narrow forests; and it was also shown that the greater the extent of wide forest, the larger the catch obtained. This is perhaps not too surprising, as it implies that larger habitats support larger populations, but the relative abundance figures themselves give no indication of the actual size of the population present.

Unlike many larger animal species that can be individually counted, it is a practical impossibility to count the number of tsetse within a given habitat. Estimates of population size must therefore be derived by indirect assessment. Numerous methods, involving a wide range of techniques and a variety of assumptions, have been devised, and an extensive literature exists on the subject, which has been reviewed by Seber (1973), Southwood (1978) and Begon (1979).

In the following paragraphs, three methods of estimating G. palpalis population size are considered for data collected on eight occasions from five localities (sectors: 6, 7, 8, 13 and 17+18), in both wet and dry seasons. The first two methods are related to each other and are based on mark-release-recapture analysis. The third method is independent of the number of marked flies released or recaptured and utilises the observed decline in daily catch during continuous trapping to estimate population size.

#### 6.5.1 Sampling Procedure.

An essentially similar sampling procedure was employed on each occasion. Early on day zero, traps were placed at pre-selected "optimal" sites, 250 to 300 meters apart along a given stretch of riverine habitat. The number of traps deployed ranged from 10 to 50, depending on the size/length of forest under study. A known number of marked G. palpalis were then released, and over the following 7 to 14 days daily collections of flies caught by each trap were made. In addition to standard catch records, the number of recaptures found in each trap was also noted. Once caught, all flies were killed (i.e. neither marked nor unmarked were returned to their habitat).

Released flies were usually of wild origin, having been caught elsewhere one or two days previously and maintained under humid, darkened conditions, during which time they were given the opportunity to feed on guinea pigs. As soon as possible after initial capture, flies were sorted and marked, using a small dot of acrylic paint on the upper thorax, before being counted and divided into sexually segregated holding cages. A small proportion of the flies died before release or were unable to fly at the time of release. These were counted, and the number actually released was determined by subtraction. For comparative purposes non-sterile, laboratory flies were sometimes also released. They were usually about one week old and had been fed on guinea pigs up until the day before release.

Most releases were made from multiple intertrap release points, but some single mass releases were also carried out from a central release point. In order to distinguish laboratory from wild flies, or those released at single as opposed to multiple release points, different marking colours or positions were used (Pollock, 1982).

#### 6.5.2 Petersen's (Lincoln Index) Method.

Begon (1979) has reviewed the various methods of estimating population abundance by mark-release-recapture analysis. In its simplest form (first used by Petersen (1896) working on young plaice in a Danish fjord; and subsequently also employed by Lincoln (1930) to assess North American waterfowl populations from bird-ringing returns) an estimate of population size is obtained from the number of recaptures ( $m$ ) found in a random sample ( $n$ ) taken from the population after initial capture, marking and release of " $r$ " individuals:

$$r/N = m/n \qquad \hat{N} = rn/m$$

Bailey (1951) has shown that for small numbers a more accurate estimate (and the one calculated here) can be obtained from the more generally applicable equation:

$$\hat{N} = r(n + 1) / (m + 1)$$

The various Petersen estimates of population size are given in table 6.2, and compared with those obtained by other methods of analysis in section 6.5.5 and figures 6.20 and 6.23.

The reliability of the Petersen estimate depends on the validity of the underlying assumptions, many of which are common to other forms of mark-release-recapture analysis, and are summarised below:

Initial capture and marking have no deleterious effects on released individuals.

Marked and unmarked individuals behave in the same way and have similar chances of survival.

Marked individuals mix thoroughly/randomly within the population being estimated, with marked and unmarked members having an equal probability of capture.

During the period between release and recapture either there are no losses of both marked and unmarked individuals, or loss rates for both are similar.

During the period between release and recapture there are no additions of either marked or unmarked individuals.

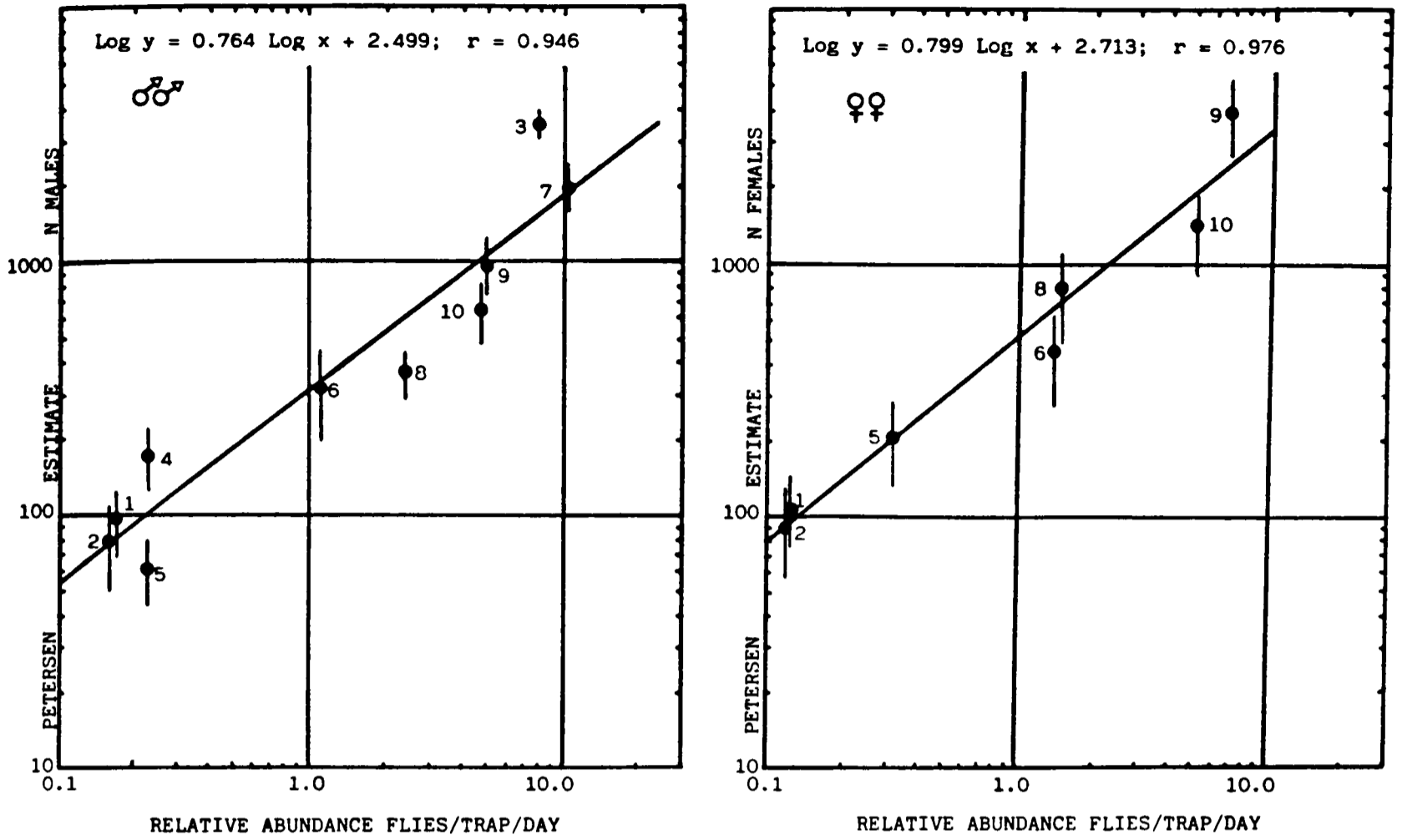
Whilst many of these assumptions may be questioned under the prevailing conditions of tsetse sampling described here, it was considered that a useful first approximation of population size could be obtained from the proportion of marked flies in the total catch over the first four-day trapping period.

TABLE 6.2 : ESTIMATES OF G. PALPALIS POPULATION SIZE.

LOCATION SECTOR HABITAT SEASON	1	2	3	4	5	6	7	8	9	10
	AKUNI* 17/18 Narrow Wet	AKUNI 17/18 Narrow Wet	EHULA* 7 Wide Dry	AKUNI* 17/18 Narrow Dry	AKUNI 17/18 Narrow Dry	MAIKUYA 13 Wide Dry	DUNGUN 6 Wide Wet	MAIKUYA 13 Wide Wet	GANYE 8 Wide Wet	EHULA 7 Wide Wet
N males	97	80	3533	173	61	323	1957	370	970	646
+/- SE	68-126	50-110	3062-4004	124-222	41-80	194-452	1528-2388	285-454	716-1224	469-824
PETERSEN										
N FEMALES	109	94	-	-	210	450	-	793	3874	1386
+/- SE	75-144	57-131	-	-	132-288	272-628	-	479-1107	2558-5190	916-1855
JACKSON										
N males	82	101	2954	182	62	295	814	345	796	686
+/- SE	63-103	70-140	2410-3599	139-231	45-82	257-337	501-1285	270-437	588-1067	580-810
N females	89	112	-	-	292	200	-	231	3038	932
+/- SE	62-1190	97-130	-	-	217-390	114-334	-	738-2023	2336-3937	714-1213
ZIPPIN										
N males	27	27	943	76	76	182	1060	205	461	519
+/- SE	22-32	22-32	875-1011	44-108	136-228	996-1124	189-221	377-545	458-580	
N females	28	28	1787	49	49	170	1445	216	435	702
+/- SE	21-35	21-35	1664-1910	43-55	43-55	116-224	1304-1586	201-231	296-574	645-757
JACKSON + ZIPPIN / 2										
N males	55	64	1949	129	69	239	937	275	629	603
N females	59	71	(1200)	(133)	171	185	(1850)	724	1737	817
RELATIVE ABUNDANCE - FLIES PER TRAP PER DAY										
Males	0.16	0.16	7.86	0.23	0.23	1.08	10.53	2.37	5.00	4.77
Females	0.12	0.12	6.43	0.32	0.32	1.42	11.72	1.47	9.9	5.13
AREA SAMPLED HA.										
	25	25	125	25	25	40	50	40	65	75
DENSITY PER HECTARE										
Males	2.2	2.6	15.6	5.2	2.8	6.0	18.7	6.9	9.7	8.0
Females	2.4	2.8	(9.6)	(5.3)	6.8	4.6	(37.0)	18.1	26.7	10.9

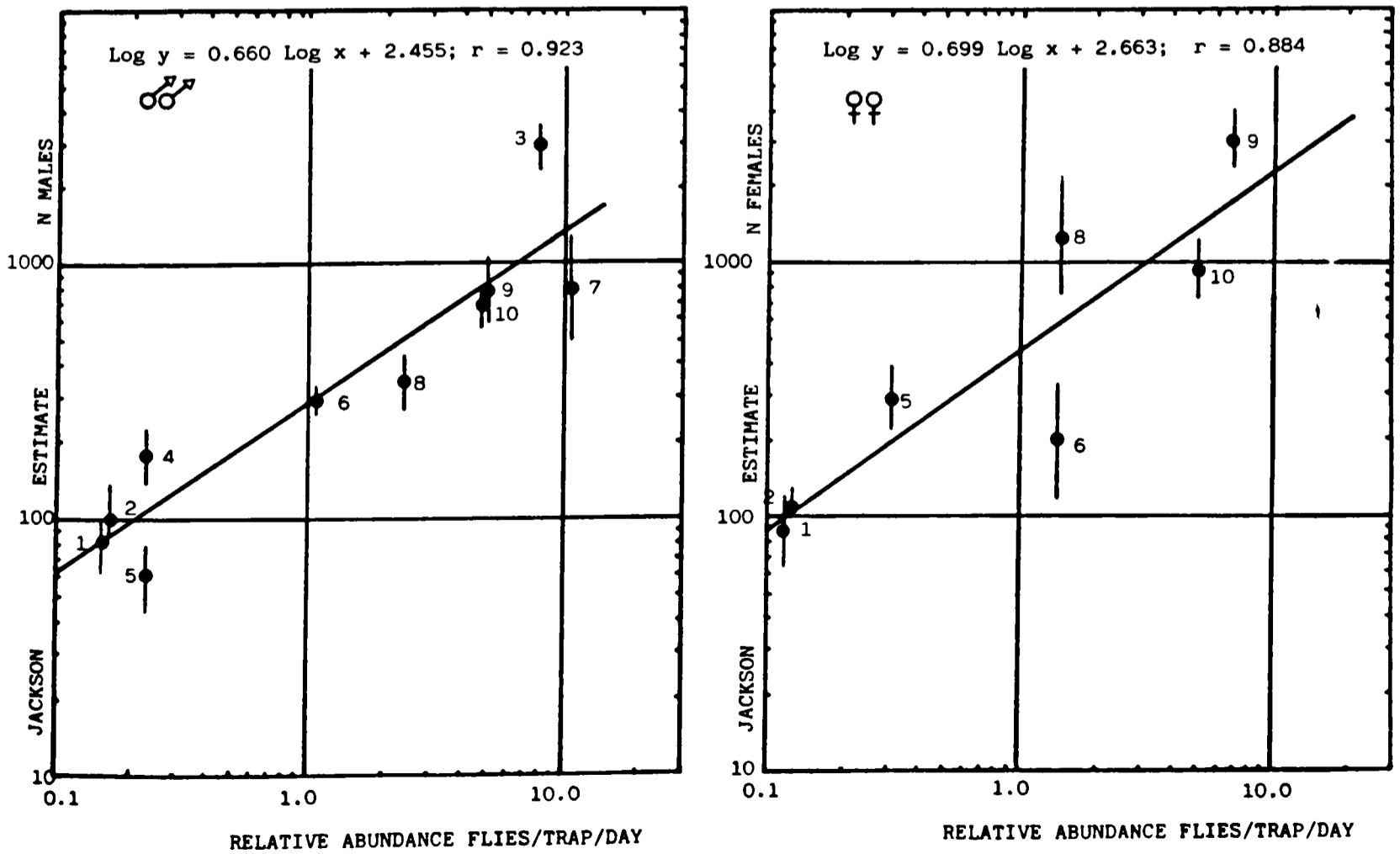
\*Jackson and Petersen estimates based on mark-release-recapture of non-sterile laboratory reared G. palpalis.

FIGURE 6.20 : PETERSEN ESTIMATES OF G. PALPALIS POPULATION SIZES



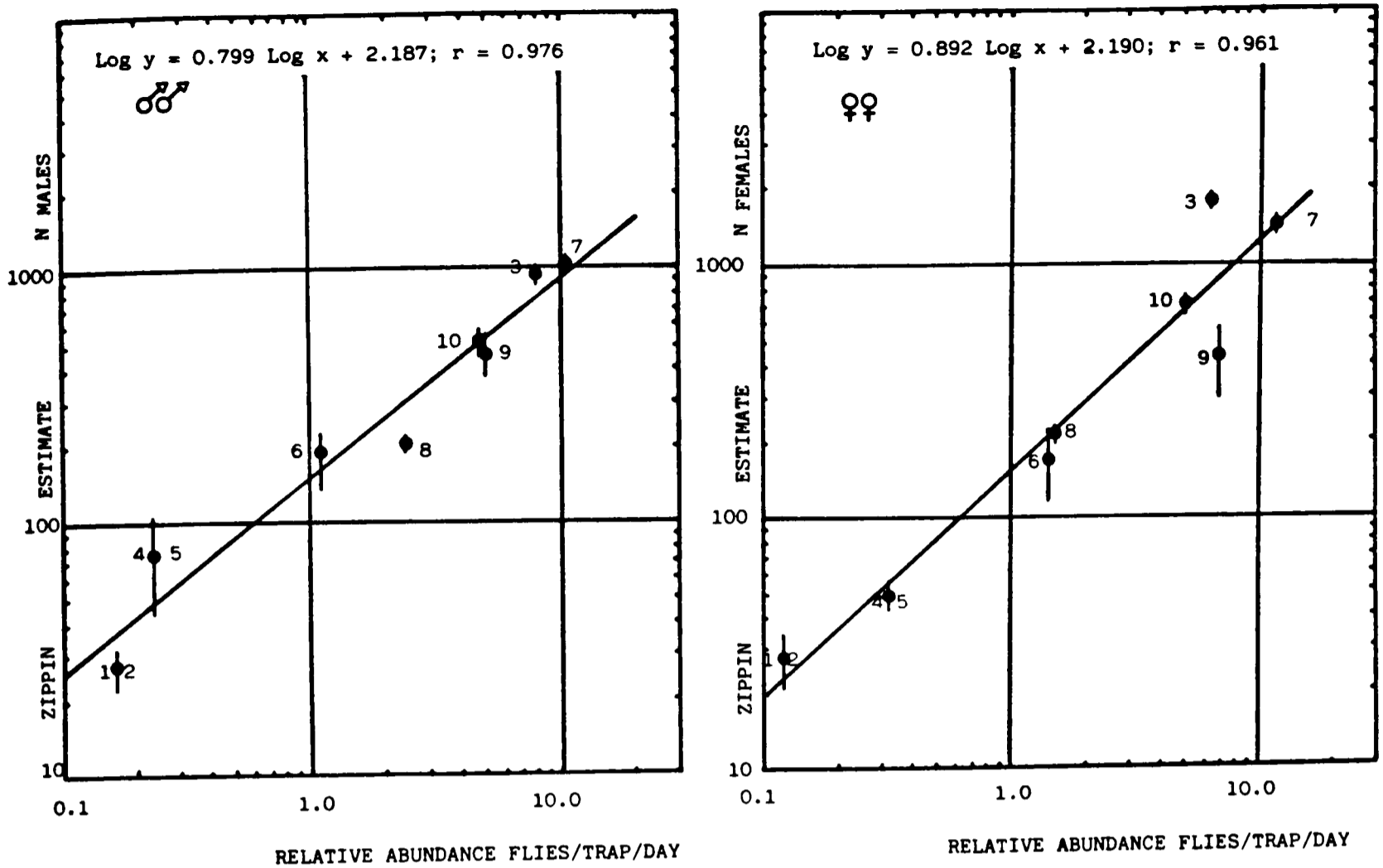
Vertical lines indicate range of +/- 1 standard error.

FIGURE 6.21 : JACKSON ESTIMATES OF G. PALPALIS POPULATION SIZES



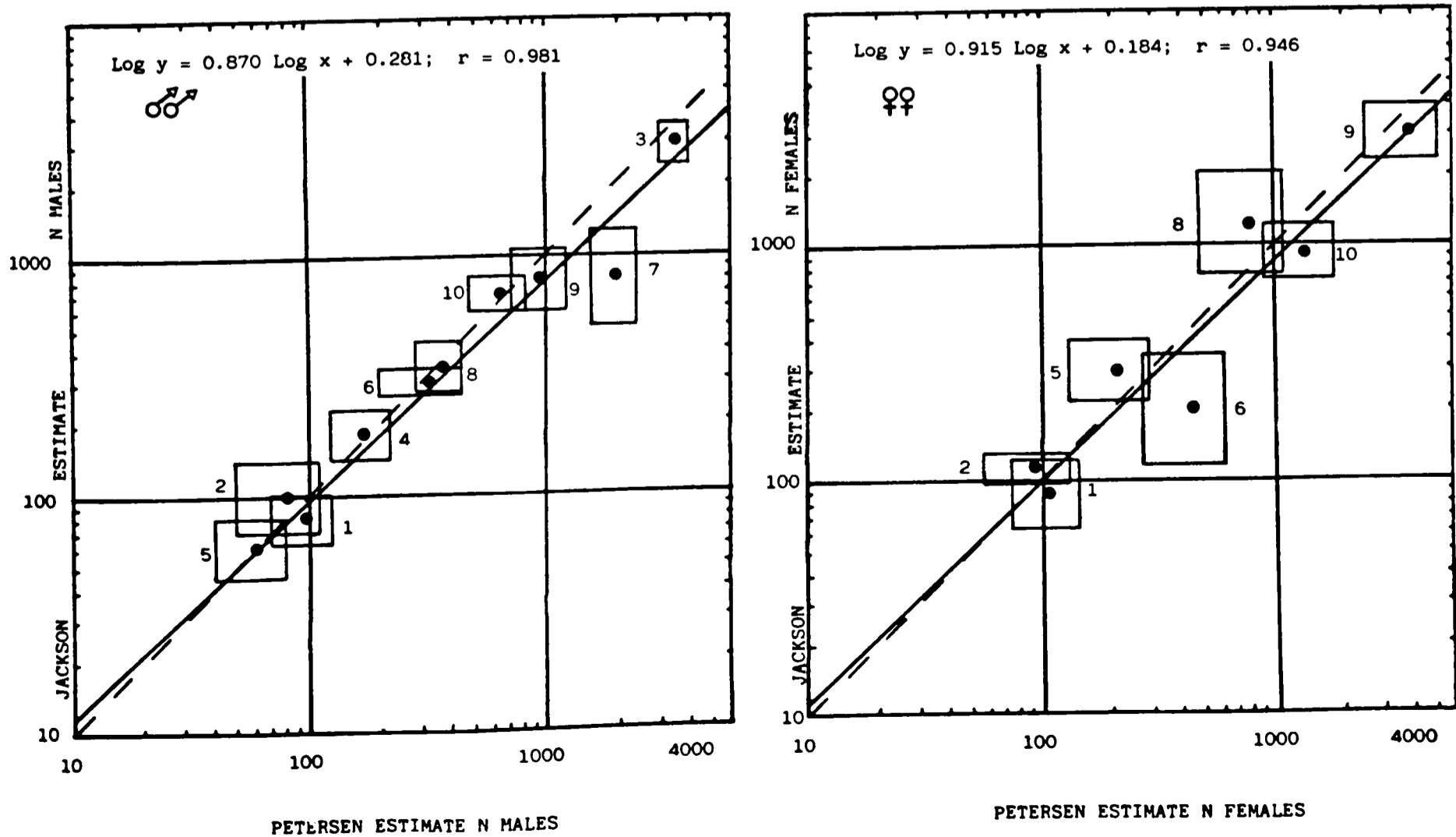
Vertical lines indicate range of +/- 1 standard error.

FIGURE 6.22 : ZIPPIN ESTIMATES OF G. PALPALIS POPULATION SIZES



Vertical lines indicate range of +/- 1 standard error.

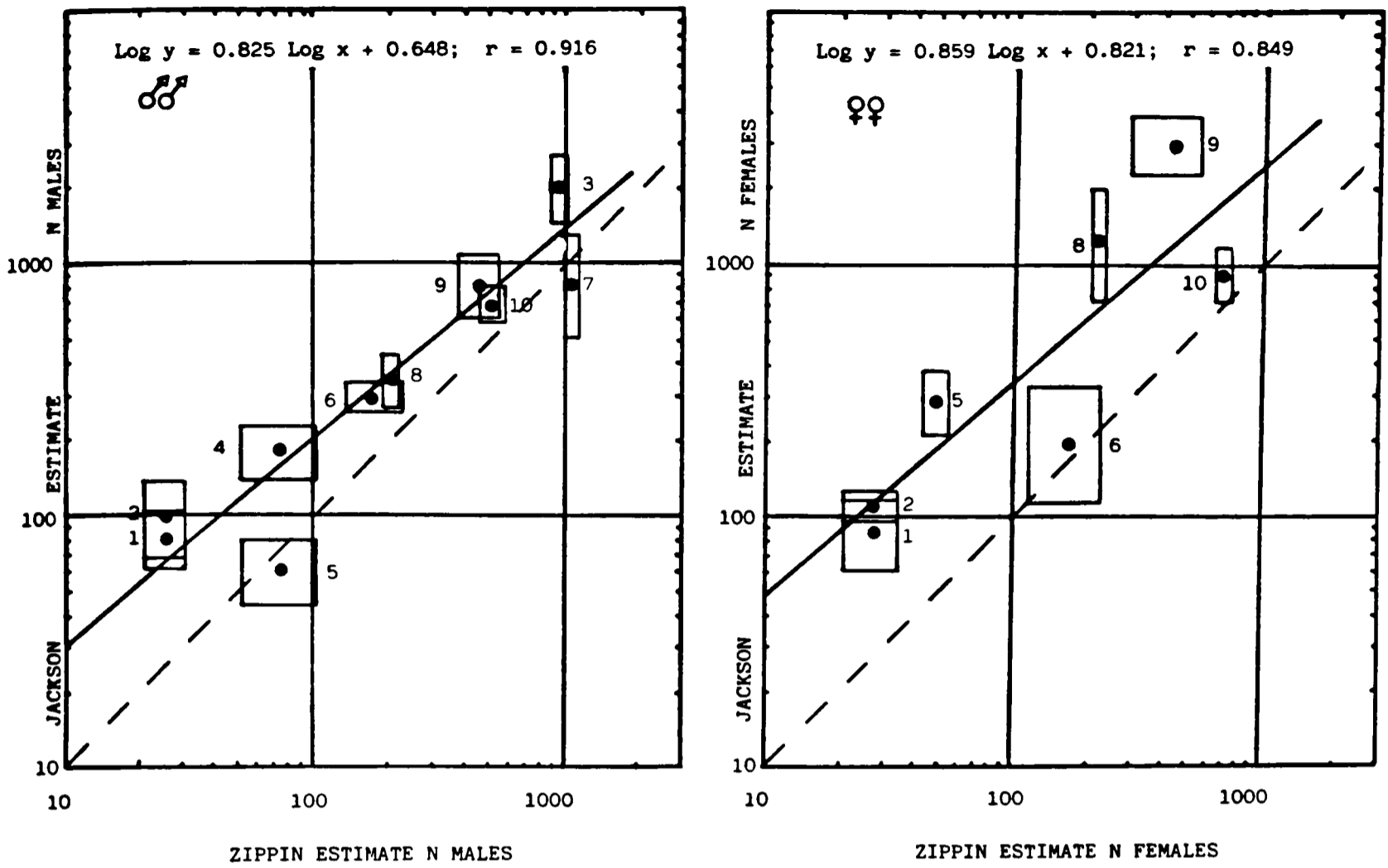
FIGURE 6.23 : COMPARISON OF JACKSON AND PETERSEN ESTIMATES OF G. PALPALIS POPULATION SIZES



Boxes indicate range of +/- 1 standard error.

FIGURE 6.24 :

COMPARISON OF JACKSON AND ZIPPIN ESTIMATES OF G. PALPALIS POPULATION SIZES



Boxes indicate range of +/- 1 standard error.

FIGURE 6.25 : BICONICAL TRAP: VISIBILITY AND TRAPPING ZONES

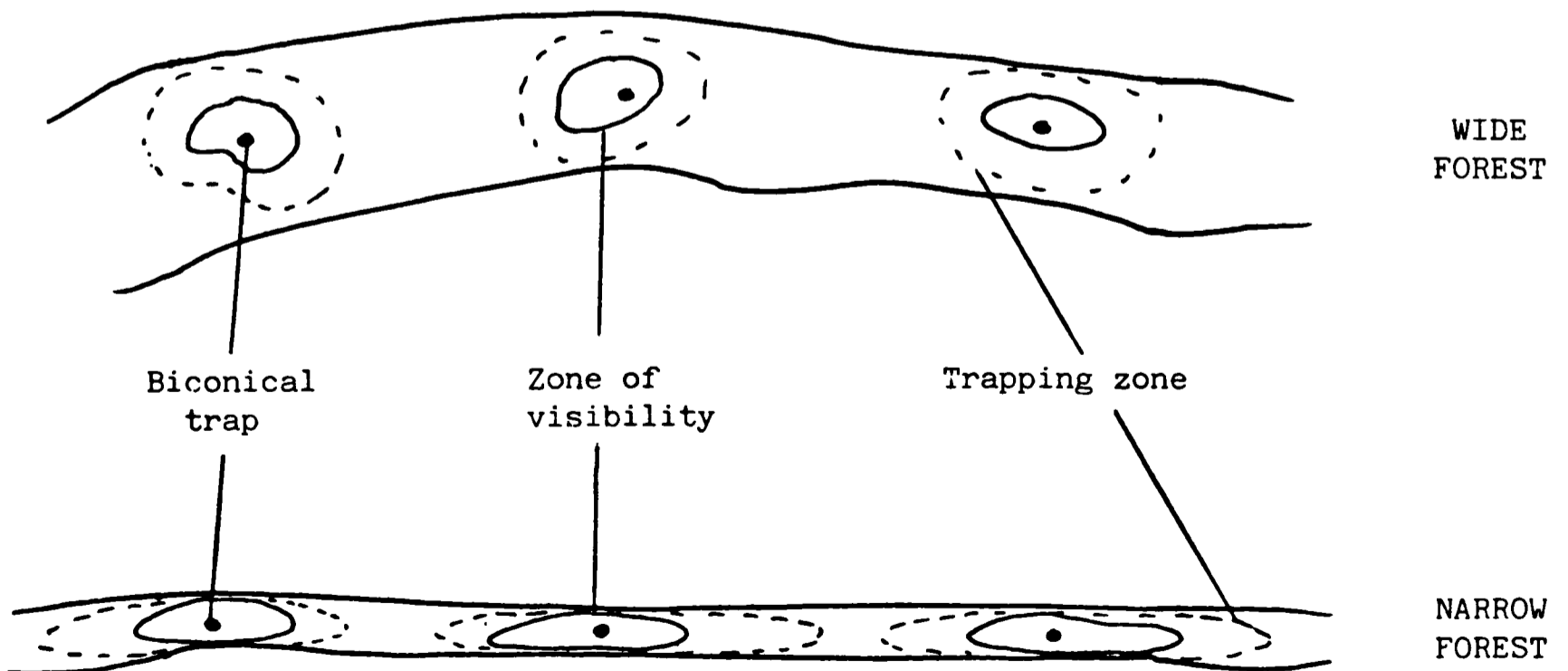
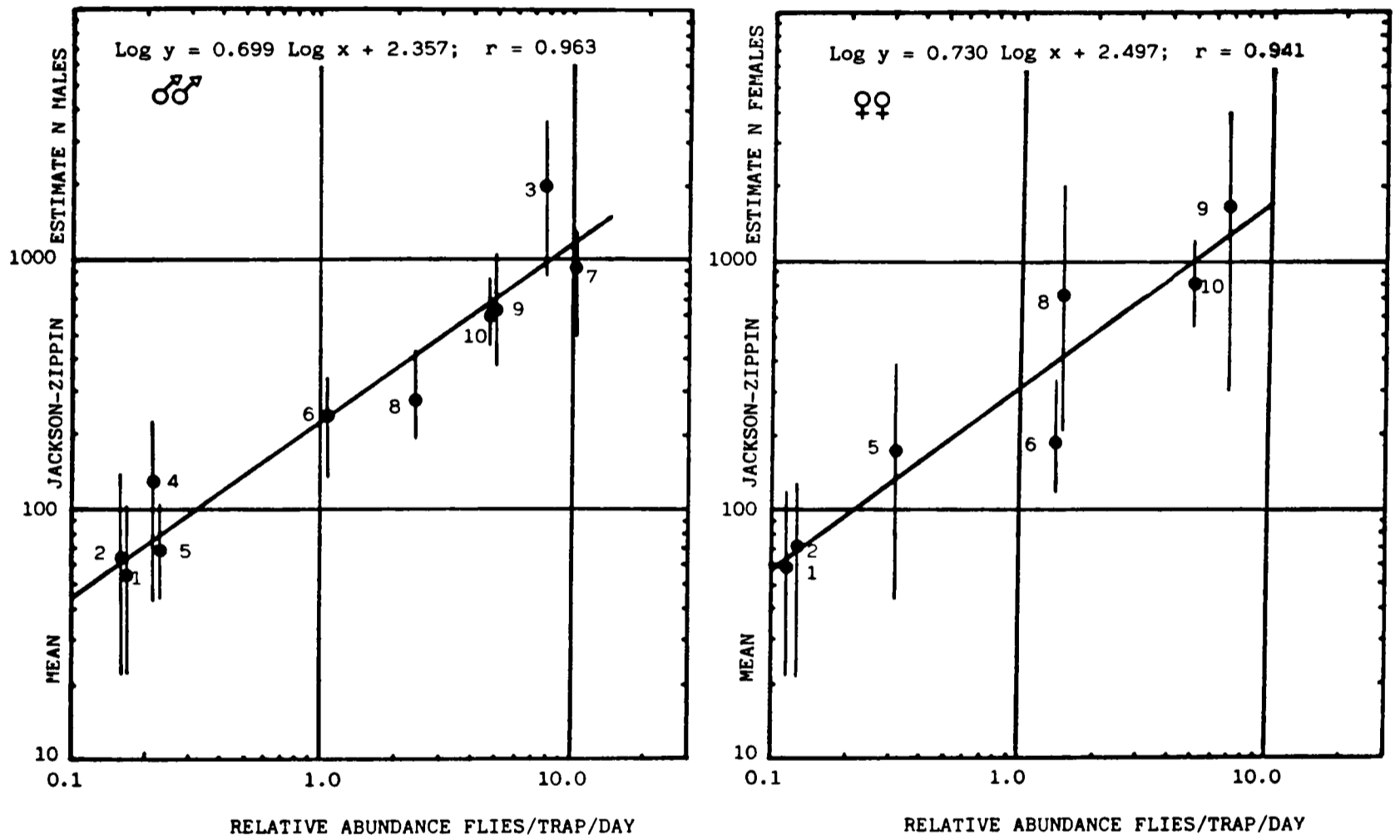


FIGURE 6.26 : MEAN VALUE OF JACKSON AND ZIPPIN ESTIMATES OF G. PALPALIS POPULATION SIZES, AGAINST RELATIVE ABUNDANCE



Vertical lines indicate maximum and minimum limits of standard error ranges of both estimates.

Over such a period, released flies would have a reasonable opportunity to mix with the unmarked population; any gains or losses from the unmarked population resulting from natural recruitment or migration were likely to have been relatively small; and any losses of marked individuals might be anticipated to be relatively low.

The crucial n/m ratio will be increased by natural recruitment and the relatively higher mortality of marked flies, both of which will lead towards an overestimation of population size; whilst the increased activity of marked flies, relative to wild ones, will decrease the ratio and tend towards underestimation.

### 6.5.3 Jackson's Positive Method.

A number of more complex methods of mark-release-recapture analysis have been developed from the basic Petersen/Lincoln concept, involving multiple release sequences and or multiple recapture occasions. Their applicability is dependent on the particular circumstances and the validity of their underlying assumptions.

The analysis considered most appropriate for the BICOT mark-release-recapture data is one derived by Begon (1979) from Jackson's (1937 & 1939) positive method, which was originally devised to estimate the size of G. morsitans populations in Tanganyika, from samples collected at weekly intervals following a single release occasion.

Jackson's method depends on determining the rate of decline in the proportion of marked individuals ( $q_i$ ) observed over "i" sampling occasions, following a single release of " $r_0$ " individuals. The proportion declines because of additions to the unmarked population through natural recruitment and immigration (which is assumed to take place at a constant rate "b"), and because of mortality experienced by marked individuals. Emigration of marked and unmarked individuals is assumed to take place at similar rates.

From the declining proportion of recaptures, the hypothetical proportion of marked flies present at the time of release ( $q_i$ ) is estimated, from which an estimate of population size is obtained.

$$\text{Essentially: } \ln q_i = i(\ln(1 - b)) + \ln q_0$$

$$\text{and: } q_0 = r_0 / \hat{N}$$

The derivation of these equations and those used to calculate standard errors are given in Begon (1979).

For uniformity, analyses of the ten data sets were restricted to collections made over the first seven days after release. The Jackson estimates of population size are given in table 6.2 and compared with those obtained by other methods of analysis in section 6.5.5 and figures 6.21, 6.23 and 6.24.

The analysis depends on similar assumptions to those listed under 6.5.2, but in contrast to the Petersen estimate (which allows for losses but not for gains) Jackson's positive method allows for both losses, and possible gains, which are assumed to be constant, and attempts to estimate them.

A further assumption of multiple recapture analysis is that sampling itself should not significantly affect the size of the population being estimated. Under the continuous trapping conditions of the sampling programme, this assumption would appear to be invalid. It may be argued however, that both marked and unmarked segments of the population experience the same trapping intensities, and thus similar proportions of both marked and unmarked individuals ought to be removed. The effect of continuous trapping can thus be considered simply as an additional cause of mortality jointly experienced by both marked and unmarked segments of the population.

A major criticism, not so far mentioned, of both forms of mark-release-recapture analysis is that neither takes account of the cyclical nature of tsetse activity - related to feeding and reproductive cycles.

Conway et al. (1974) have shown that mark-release-recapture analysis, using a modified version of the Fisher and Ford (1947) method, based on the recapture of synchronously fed and released mosquitoes (Aedes aegypti) in an old car dump in Tanzania, resulted in significant overestimates of population size. This was because the activity cycles of released mosquitoes were all in phase with each other, and not typical of the population at large. Recapture peaks occurred at four day intervals, with lower levels of recapture in the intervening periods. Thus generally fewer recaptures were obtained than would otherwise have been expected - resulting in overestimation of population size.

Rogers (1977) and Rogers & Randolph (1982) have shown a similar periodicity in the recapture of male G. fuscipes fuscipes in Uganda, and both male and female G. palpalis gambiensis in Ivory Coast, and have suggested that the various recapture peaks are a function of feeding and ovulation cycles. G. palpalis palpalis in Nigeria probably has a similar pattern of activity, but analysis of the recapture data was inconclusive. This may have been because of the limited duration of the recapture series, but may also have been due to differences in methodology.

All mosquitoes released by Conway et al. (1974) were fed at the time of capture and immediately released. Rogers and Randolph (1982) did not feed their flies before release, but argued that as all were caught in biconical traps, and marked and released soon after initial capture, flies were likely to be at similar (hungrier) stages of their activity cycles and thus exhibited synchronous behaviour after release.

All G. palpalis released in Nigeria, however, were given the opportunity of feeding prior to release - a high proportion, but not all, engorged themselves. How synchronised they were at release is therefore a debatable point, but it is likely that to some degree they were. It follows that the mark-release-recapture estimates obtained are likely to be overestimates of real population size.

#### 6.5.4 Zippin's Removal Trapping Method.

As previously mentioned, in section 6.3.7, a feature of continuous trapping of G. palpalis, with numerous traps in relatively limited habitats, was the progressive decline observed in daily catch. It

seems highly probable that this decline was a direct result of removal of individuals by previous trapping and reflected an overall reduction in the population size. If the number of individuals removed is known and the rate of decline in daily catch is calculated, the original size of the population can be determined.

Southwood (1978) described three alternative approaches to the analysis of removal trapping data, and considered that the most accurate was that originally developed by Moran (1951), and subsequently considerably simplified by Zippin (1956 and 1958). Zippin's multinomial method is the one used here.

For uniformity, analysis was restricted to data collected over the first seven days. The various Zippin population estimates are given in table 6.2, and compared with those obtained by other methods of analysis in figures 6.22 and 6.24.

The various assumptions upon which this method depends were given by Moran (1951) and are summarised below:

The method of capture should not influence the subsequent probability of individuals being caught.

The population should be stable during the capture period, i.e. there should be no significant natality, mortality (other than by trapping), immigration or emigration.

Catching of one individual does not interfere with the capture of others.

The chances of being captured must be equal for all individuals.

The first and third assumptions would appear to hold for biconical trapping.

Clearly the second assumption is not valid for continuous trapping of tsetse populations. During the relatively short periods under consideration, the wild population is likely to experience some recruitment and mortality, but with the low intrinsic rates of growth of tsetse populations it is unlikely to be great. The net result of including an element of daily recruitment in the daily catch is a tendency for overestimation of population size. Immigration would be important if only part of the habitat was being trapped, but in the circumstances under consideration here a high proportion of the habitat contained traps, and thus effectively there were no external sub-populations which could provide immigrants.

The fourth assumption is the most problematic, for obviously the chances of an individual tsetse being caught by a biconical trap depends, in the first instance, on the fly being in visible range of the trap. It might be argued that with traps spaced at approximately 250 to 300 meter intervals in the heart of generally very restricted habitat, no fly should be further than 125 to 150 meters from a trap and that relatively limited flight activity in search of hosts should bring most flies within range of at least one trap. However, flies are unlikely to fly in straight lines and are inactive for considerable periods. Given sufficient time, most flies were likely to come into visible range of the stationary traps, but the dramatic initial decline in daily catch usually observed over the first 4 to 5 days of continuous trapping was thought more likely to be the result of trapping out of individuals in the immediate vicinities of the traps. The area involved around each trap (the trapping zone) will be somewhat greater than the trap's visible range, dependent on the rate of dispersal. (See figure 6.25)

If this interpretation is correct, then the removal trapping population estimate is for the tsetse population within the trapping zones around each trap, and thus will underestimate the population as a whole. The degree of underestimation will depend on the proportion of available habitat that the trapping zones occupy. Where trapping zones covered a high proportion of available habitat (narrow forests) the degree of underestimation would be low; while in more extensive wide forest habitats the degree of underestimation would be greater. In general however it is considered that this underestimating bias is likely to more than offset any overestimation due to recruitment mentioned earlier in this section.

#### 6.5.5 Comparison of G. palpalis Population Estimates.

The results obtained from the three methods of analysis for the ten data sets are given in table 6.2. Population estimates and their standard errors were calculated separately for males and females.

For comparative purposes the estimates obtained by each method were plotted against their corresponding relative abundance (number of unmarked males or females caught per trap per day, over the first two days). The Petersen estimates are shown in figure 6.20; the Jackson estimates in figure 6.21; and the Zippin estimates in figure 6.22. The number against each data point indicates the relevant data set, and the vertical lines represent +/- one standard error. Base ten logarithmic scales have been used in order adequately to cover the wide range of values obtained (population estimates from 20 to 5000+; relative abundance from 0.1 to 10+). This scaling tends to highlight differences at lower values and mask differences at higher values.

Both male and female G. palpalis population estimates were highly correlated to relative abundance; Petersen and Zippin estimates generally showed better correlations than those from Jackson's method. For any particular method, the slopes of the regressions for the two sexes were not significantly different, but for a given relative abundance, female population estimates were higher than corresponding male estimates.

Standard errors of male estimates were generally smaller than those for females, although both increased with the size of the population estimate.

Standard errors of Zippin estimates were generally lower than those based on mark-release-recapture analysis.

Petersen and Jackson estimates, for both males and females, were found to be in good general agreement. Figure 6.23 shows them plotted against each other. Perfect 1 : 1 correspondence is represented by the dashed line; the solid lines being the best fit regression of the two estimates, which does not diverge significantly from the diagonal. The boxes indicate +/- one standard error limits of each estimate.

In contrast, Zippin removal trapping estimates were not in such close agreement with those obtained from mark-release-recapture estimates, although they were generally lower. This is illustrated in figure 6.24, in which the regression lines lie well above the 1 : 1 diagonal. The differences were most marked for females, as indicated by the greater divergence of their regression line from the diagonal.

As previously mentioned, there are reasons to believe that mark-release-recapture estimates are likely to overestimate population size, whilst removal trapping estimates may result in underestimation. It can therefore be argued that the actual number of individuals present should lie somewhere between the two, and that a mean value should provide the most realistic estimate of population size. Figure 6.26 shows mean values of Jackson and Zippin population estimates plotted against relative abundance. The vertical lines in this case show the maximum and minimum limits of +/- one standard error ranges of the original estimates.

Without independent knowledge of the number of individuals present, the accuracy of these mean estimates of population size and the reliability of their relationship with relative abundance would have to remain a matter of conjecture. Indirect validation of the relationship can however be obtained, for males at least, from the results of the BICOT pilot release programme, details of which are given in appendix 1.

Known, large numbers of differentially marked, 3 to 4 day old, sterile male G. palpalis were released at two-weekly intervals in Tsakuwa forest (sector 12). Sample catches were collected over two-day periods each week. Declining recapture rates in weeks following a given release indicated mortality levels of between 10% and 15% per day amongst sterile males. The number of survivors ( $N_s$ ) after release was subsequently estimated from the equation:

$$N_s = N_r \cdot e^{-mt}$$

where " $N_r$ " was the number originally released, and " $m$ " was the mortality rate per unit time " $t$ ".

The number of survivors from each release was calculated at weekly intervals, corresponding to the trap sampling period, for both 10% and 15% mortality levels. The results are presented in table 6.3, together with the number predicted from the relationship between relative abundance and mean Jackson-Zipin estimates.

The results are in surprisingly good agreement, with all except one of the Jackson-Zipin predictions falling within the limits determined by survival probability. Figure 6.27 shows predicted values plotted against those estimated at a 12.5% daily mortality. It would appear therefore that there are good grounds for believing that population estimates based on mean Jackson-Zipin values are reasonably accurate.

#### 6.5.6 Tsetse Density.

So far, comparisons have been made between relative abundance and estimated population size, within selected sampling zones, which have usually occupied only a portion of a given sector habitat. An alternative measure, with potentially wider applicability, would be an assessment in terms of individuals per unit area of habitat.

Although in principle the determination of density from population estimates should be a simple matter, it is difficult in practice reliably to assess the area of habitat actually sampled. Not only has man substantially modified and reduced forest cover since the last series of aerial photographs was taken, but the extent of suitable habitat within a given riverine forest is likely to change with season.

TABLE 6.3: ESTIMATED AND PREDICTED NUMBER OF SURVIVORS FOLLOWING FOUR SEPERATE RELEASES OF KNOWN NUMBERS OF MARKED STERILE MALES IN TSAKUWA FOREST - SECTOR 12.

N STERILE MALES RELEASED	DAYS AFTER RELEASE	STERILE MALE RELATIVE ABUNDANCE	JACCKSON-ZIPPIN PREDICTION	ESTIMATED NUMBER OF SURVIVING STERILE MALES			
				m=0.1	m=0.125	m=0.15	
2 895	a	5-6	2.66	451	516	450	392
	b	12-13	1.00	228	256	188	137
	c	19-20	0.11	49	127	78	48
	d	26-27	0.06	30	63	33	17
3 922	e	5-6	1.86	351	532	464	404
	f	12-13	0.94	219	264	193	141
	g	19-20	0.06	30	131	81	49
	h	26-27	0.06	30	65	34	17
4 1470	i	5-6	6.44	838	848	739	644
	j	12-13	3.31	525	421	308	225
	k	19-20	0.69	176	209	128	79
5 1242	l	5-6	4.69	671	717	625	544

Letters identify points in Figure 6.26.

FIGURE 6.27 : RELATIONSHIP BETWEEN ESTIMATES OF THE NUMBER OF STERILE MALES REMAINING AFTER RELEASE, BASED ON JACKSON-ZIPPIN PREDICTION FROM THEIR RELATIVE ABUNDANCE, AND THEIR PROBABILITY OF SURVIVAL (  $m = 0.125$  )

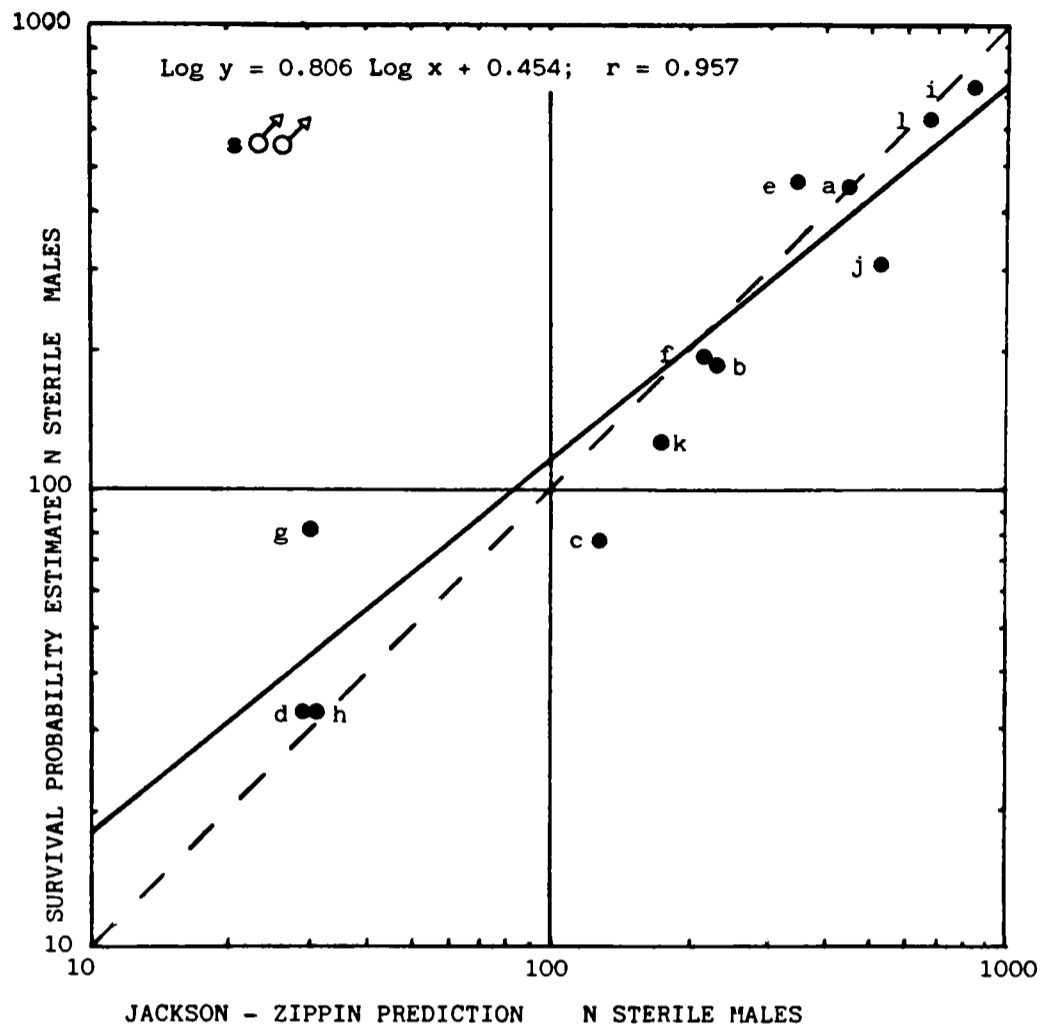
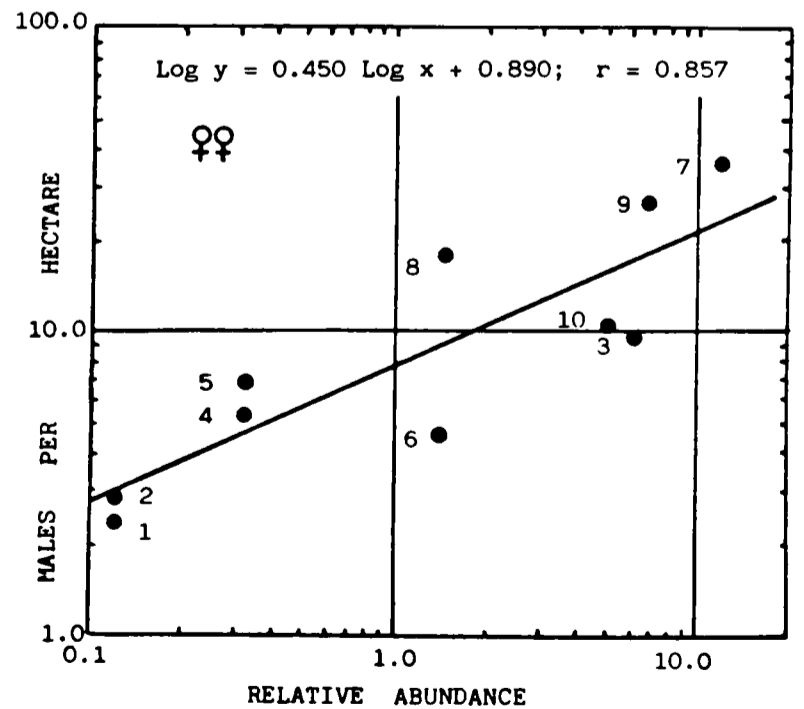
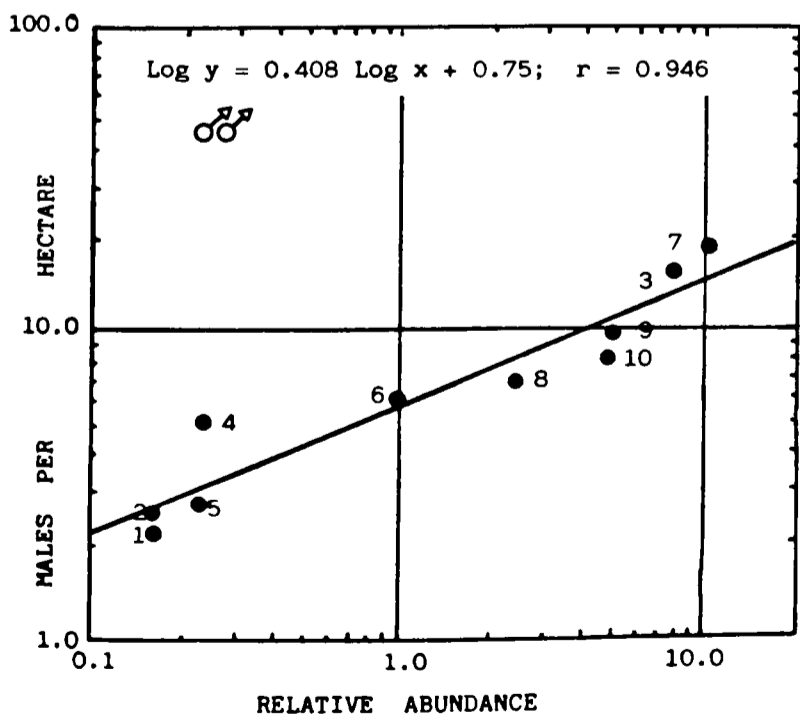


FIGURE 6.28 : DENSITY OF G. PALPALIS PER HECTARE OF FOREST HABITAT, BASED ON MEAN VALUE OF JACKSON AND ZIPPIN ESTIMATES OF POPULATION SIZE



Nevertheless crude habitat area estimates have been made for each of the sampling zones. No distinction has been made between wide and narrow riverine forest - the area of the latter has been determined on the basis of length and an assumed constant width of 20 meters. Area and G. palpalis density estimates are given in table 6.2, and are also plotted against relative abundance in figure 6.28.

G. palpalis density in the Feferuwa and Akuni catchments would appear to be low; ranging from 2 to 20 males and 2 to 40 females per hectare of forest habitat. When the small proportion of total land area actually occupied by riverine forest (less than 5%) is taken into consideration, the overall density is reduced still further, to the region of 10 to 100 males, and 10 to 200 females per square kilometer of land.

#### 6.6 Assessment.

In the past, four tsetse species occurred within the BICOT project area. G. morsitans has disappeared, and G. longipalpis was found to be confined to Pandam Wildlife Park. Despite high human population density and intensive cultivation, both G. palpalis and G. tachinoides persisted within the area. Their distribution was limited to riverine vegetation, which occupied only 5% of the land area. G. palpalis formed more than 90% of the total catch from biconical traps over a two year period.

The relative abundance of G. palpalis in each sector was found to increase, with increasing extent of wide forest habitat. An equation defining this relationship enables predictions of relative abundance

to be made from the area of wide forest, that can be determined from aerial photographs or satellite imagery.

In contrast to G. palpalis, the relative abundance of G. tachinoides was found to be higher in southern and western sectors, where land use intensity was greatest and riverine vegetation had been most severely disturbed by human activity.

Mark-release-recapture and removal trapping estimates of population size indicated low levels of G. palpalis within narrow forest habitats, of between 2 and 5 males, and 2 and 10 females per hectare of narrow forest. In wide forest habitats, density estimates ranged from 6 to 19 males, and 5 to 37 females per hectare. Equations relating population estimates to relative abundance were defined, which enable predictions of population size to be made from relative abundance.

Highest catches of both G. palpalis and G. tachinoides were associated with riverine forest crossing points. In the virtual absence of wildlife, it appeared that both species were dependent on cattle and/or man for their survival.

Prolonged trapping with many biconical traps, in limited tsetse habitats, resulted in substantial decreases in the number of tsetse caught and marked qualitative changes in the composition of the catch, which were indicative of population reduction. Elsewhere in West Africa, biconical traps have been used, for example, to reinforce barriers created to prevent/reduce reinvasion in Upper Volta (Cuisance et al., 1979), and in Ivory Coast, insecticide impregnated biconical

traps have been used to control riverine tsetse populations (Laveissiere and Couret, 1979). In the BICOT pilot release programme, described in appendix 1, biconical traps were used to suppress wild G. palpalis populations prior to the release of sterile males.

Major riverine crossing points can be identified from aerial photographs, and of course villagers and cattle owners have an intimate knowledge of paths and watering points. An appropriate form of self-help tsetse control would be to provide, subsidize and/or otherwise encourage the local manufacture, and individual use of biconical traps.

7. CATTLE DISTRIBUTION AND ABUNDANCE IN A REGION OF THE NIGERIAN SUB-HUMID ZONE, NORTH-EAST OF LAFIA, PLATEAU STATE.

7.1. Background.

The International Livestock Centre for Africa (ILCA) is currently investigating livestock production systems within the Nigerian sub-humid zone and has carried out a series of livestock and natural resource aerial surveys (Milligan, Bourn and Chachu, 1979; ILCA, 1980). It was decided to include the BICOT project area in the aerial survey programme in order to assess the number and distribution of cattle prior to the initiation of tsetse control operations.

This chapter, based on an unpublished report (Bourn and Milligan, 1982), describes the methodology and results of that aerial survey, which took place at the end of the dry season, on 13 April 1982.

7.2 Methodology.

7.2.1 Flight Procedure.

The aerial survey of the BICOT project area was carried out from Haipang airport on the Jos plateau, using the ILCA aircraft, a high-winged, twin engine, Partenavia P68B, equipped with an OMEGA global navigation system and a radar altimeter. The four man survey team consisted of the pilot; two observers, seated behind the pilot, each responsible for recording livestock observed to the left or right of the aircraft; and a front seat observer, who navigated and recorded land use, habitation and ecological conditions.

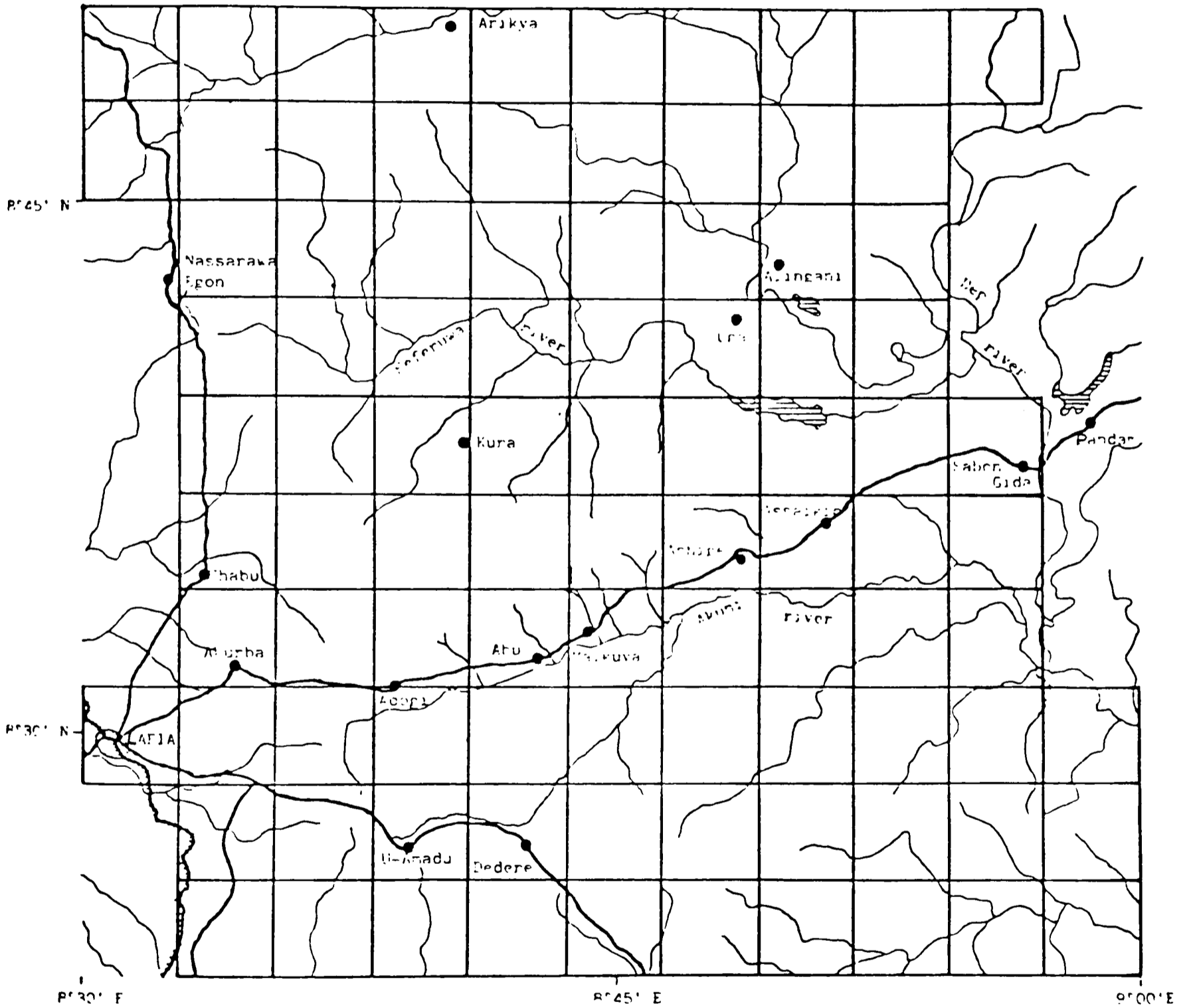
A systematic pattern of parallel flight lines was flown at five kilometer intervals over the survey zone, centred at  $8^{\circ}40'N$  and  $8^{\circ}45'E$ . Starting at the north-western corner, some ten kilometers north of Nassarawa Egon at the edge of the Mada escarpment, the aircraft flew alternately eastwards and westwards between the Dep river and the main Akwanga to Lafia road.

Each flight line was divided into five kilometer sectors, thus enabling the information collected to be recorded on a five by five kilometer grid, as shown in figure 7.1. Ten flight lines, varying in length from 40 to 50 kilometers, were flown, and 93 grid squares were covered. The total land area surveyed was 2,325 square kilometers.

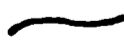
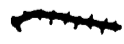


#### 7.2.2 Sampling Procedure.

The area actually sampled along each flight line was restricted to fixed strips on each side of the aircraft. The width of these strips was determined by the projection from the observer's eye to the ground, of two parallel rods supported by the wing struts. The spacing of the two rods was calculated for each observer using the methods described by Norton-Griffiths (1978), and set to give a ground strip width of 400 meters when flying at an altitude of 800 feet (244 meters) above ground level. Thus, with flight intervals of five kilometers, and a combined left and right sample strip width of 800 meters, an overall sampling intensity of 16% of the land area was obtained.

FIGURE 7.1 : GRIDDED AERIAL SURVEY BASE MAP OF BICOT PROJECT AREA



Each grid square 5km x 5km. Approximate scale 1 : 350,000

-  Major roads.
-  Railway line.
-  Rivers and streams.
-  Lakes.

### 7.2.3 Information Collection.

The two back seat observers recorded the number of cattle seen within their respective sample strips on each side of the aircraft. For every herd seen, a visual estimate of the number of animals was recorded. If more than ten animals were present, a photograph was taken using a 35mm camera fitted with a zoom lens, and 200 ASA colour film, so that subsequently the actual number of animals could be accurately counted.

The patterns of land use, vegetation and habitation were recorded by the front seat observer, who also estimated the proportion of grass and tree cover, the extent of burning, the composition of the natural vegetation, the type and intensity of cultivation, and human habitation.

### 7.2.4 Information Analysis.

After the flight, the number of animals in each photograph was accurately counted by projecting the colour slide in a micro-fiche reader. The results obtained were then compared to the visual estimates made during flight, and the bias of each observer calculated. This bias factor was then used to correct the estimates of large herds that could not be photographed, or where the quality of the photograph was too poor for counting.

After correcting all the cattle estimates made during the survey, the total numbers of animals and herds seen along each flight line were calculated by pooling the observations made on each side of the aircraft. Each flight line was treated as an independent sample of the

total animal population, from which an overall population estimate, with confidence limits, was computed using the "ratio method" recommended by Jolly (1969), and covered in detail by Norton-Griffiths (1978).

This ratio estimate assumes that the larger the sample unit (flight line), the more reliable the count obtained from it. The calculation thus biases the overall variance in favour of the longer flight lines, by taking into account the co-variance between the individual sample areas and the animals counted within them.

Other environmental information collected during the survey was converted, where necessary, to standard density values, and analysed by computer using programmes available in the Statistical Package for Social Sciences (SPSS, 1982).

### 7.3. Results.

The results of the aerial survey, covering some 2,325 square kilometers at a 16% sampling intensity, are summarised in table 7.1 and figures 7.2 to 7.6.

#### 7.3.1 Cattle Population.

The number of cattle within the survey zone was estimated to be 38,138 (+/-17% standard error). The mean density was 16.4 head per square kilometer; the stocking rate being 6.1 hectares per head. The distribution of cattle in terms of density and stocking rate is shown in figures 7.2 and 7.3.

TABLE 7.1 : SUMMARY OF RESULTS FROM AERIAL SURVEY OF BICOT PROJECT AREA

Date of survey	13 April 1982
Size of survey zone, km <sup>2</sup>	2,325
Total cattle population (+/-% SE)	38,138 (17%)
Mean cattle density, head/km <sup>2</sup>	16.4
Stocking rate, ha/head	6.1
Total number of herds (+/-% SE)	506 (13%)
Mean herd density, herd/km <sup>2</sup>	0.22
Mean herd size, head/herd	75.4
Modal herd size, head/herd	20 - 40

TABLE 7.2 : CORRELATION MATRIX OF LAND USE/VEGETATION VARIABLES RECORDED DURING AERIAL SURVEY OF BICOT PROJECT AREA

	CATTLE NUMBER	ARABLE HABIT.	FULANI HABIT.	GRASS COVER	WOOD-LAND	SCRUB-LAND	CULTIVATION	RIVERINE FOREST
CATTLE NUMBER	1.000							
ARABLE HABIT.	-.063	1.000						
FULANI HABIT.	.164	-.034	1.000					
GRASS COVER	.039	.163	.028	1.000				
WOOD-LAND	-.085	-.097	-.026	-.194*	1.000			
SCRUB-LAND	.160	-.126	-.097	-.110	-.358***	1.000		
CULTIVATION	-.083	.207**	.074	-.096	-.225**	.219**	1.000	
RIVERINE FOREST	.236**	-.107	-.071	.193*	-.203*	.048	-.083	1.000

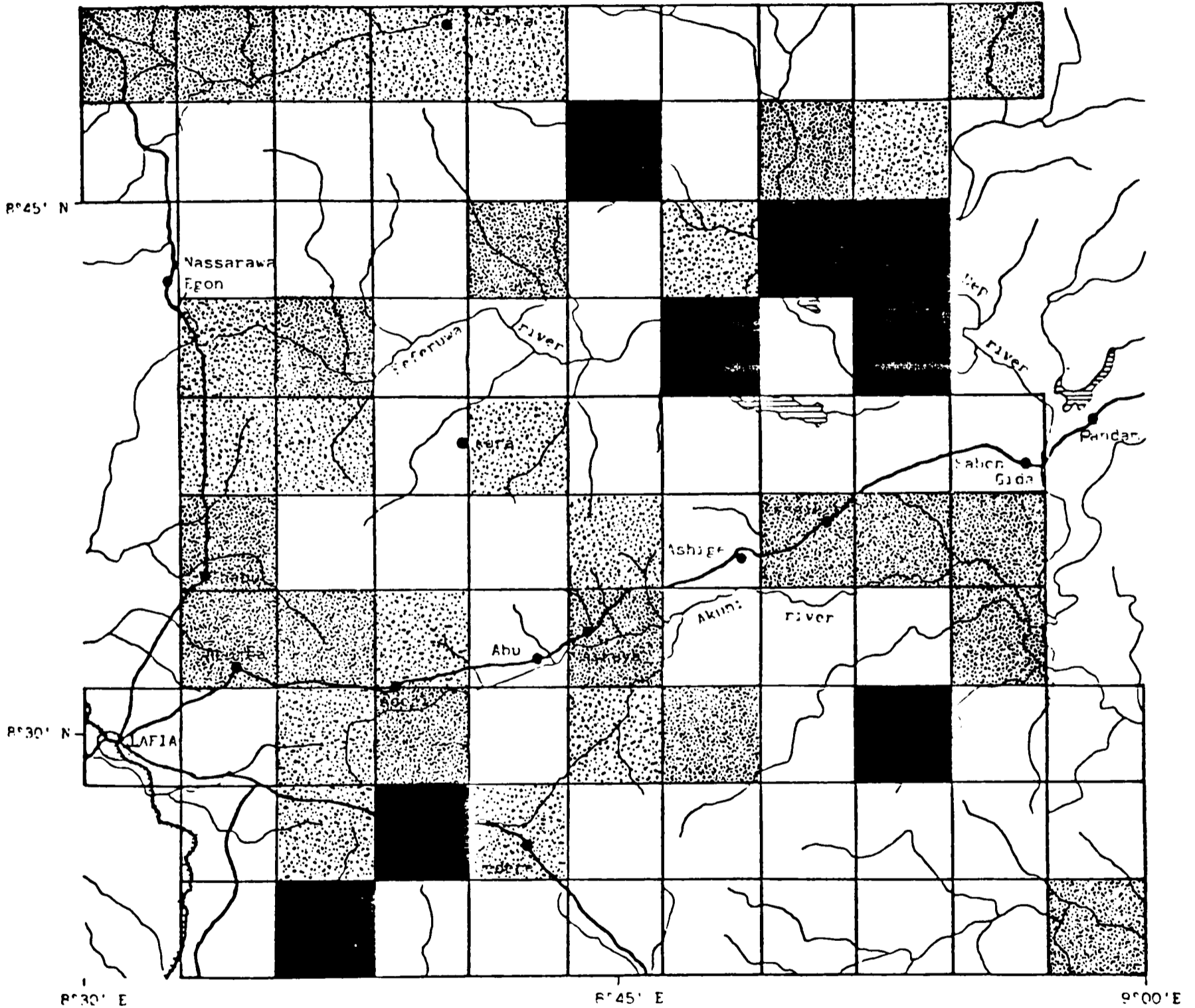
Significance levels: \* 90% probability; \*\* 95% probability; \*\*\* 99% probability.

TABLE 7.3 : SUMMARY OF SEASONAL CATTLE POPULATION AND DENSITY ESTIMATES, FROM LOW LEVEL AERIAL SURVEYS IN NIGERIA

SURVEY ZONE	AREA km <sup>2</sup>	ESTIMATED CATTLE POPULATION (+/-%SE)		CATTLE DENSITY km <sup>2</sup>	
		DRY SEASON	WET SEASON	DRY	WET
KURMIN BIRI*	2,500	43,180 (9%)	10,410 (26%)	17.3	> 4.2
ABET*	2,475	92,440 (8%)	56,275 (6%)	37.4	> 22.7
MARIGA*	2,750	18,175 (16%)	64,485 (8%)	6.6	< 23.5
LAFIA SE*	3,500	44,420 (19%)	131,845 (14%)	12.7	< 37.7
JOS PLATEAU#	8,600	141,402 (11%)	402,096 (13%)	16.4	< 46.8
LAFIA NE (BICOT)	2,325	38,138 (17%)	?	16.4	?

\* Milligan, Bourn and Chachu, (1979). \* ILCA, (1980).

FIGURE 7.2 : CATTLE DENSITY



Each grid 5km x 5km. Approximate scale 1 : 350,000.









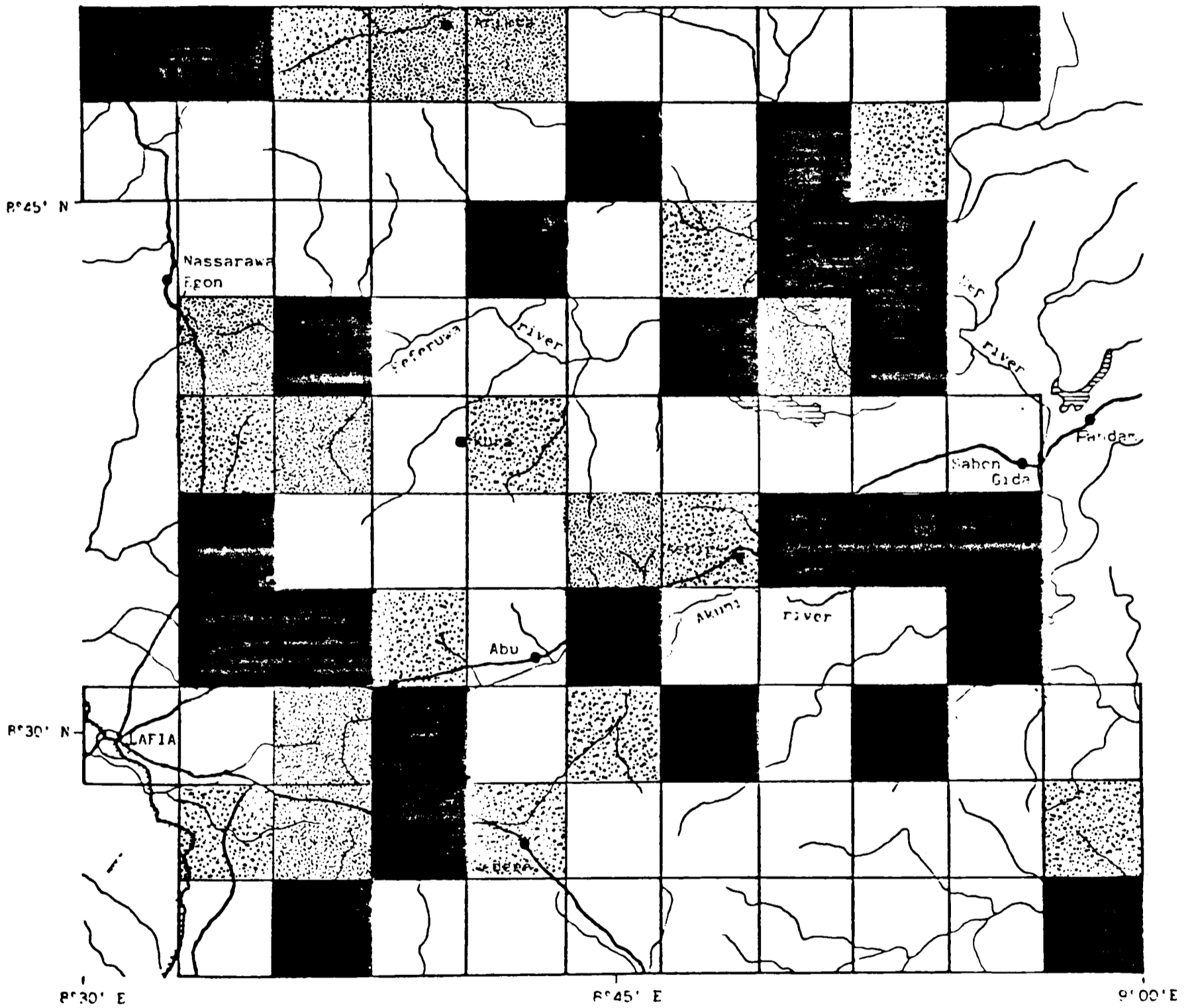
- |   |                     |   |                                 |
|---|---------------------|---|---------------------------------|
|  | Major roads.        |  | >50 cattle km <sup>-2</sup>     |
|  | Railway line.       |  | 25 - 49 cattle km <sup>-2</sup> |
|  | Rivers and streams. |  | 5 - 24 cattle km <sup>-2</sup>  |
|  | Lakes.              |  | <4 cattle km <sup>-2</sup>      |

FIGURE 7.3 : CATTLE STOCKING RATE



Each grid square 5km x 5km. Scale approximately 1 : 350,000.



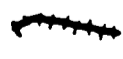





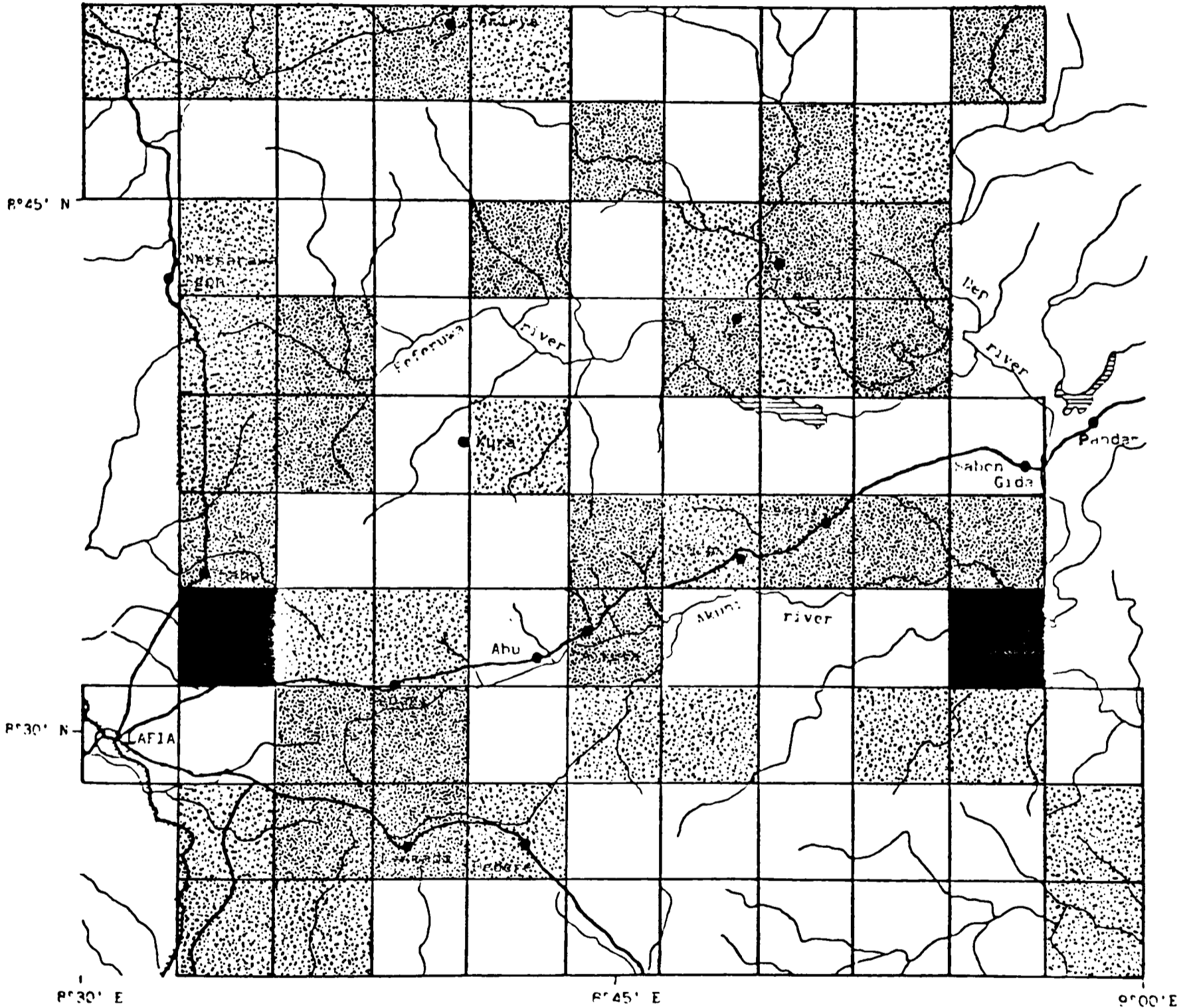
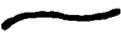







- |   |                     |   |                   |
|---|---------------------|---|-------------------|
|  | Major roads.        |  | < 4 hectares/head |
|  | Railway line.       |  | 5 - 9 " "         |
|  | Rivers and streams. |  | 10 - 49 " "       |
|  | Lakes.              |  | > 50 " "          |

FIGURE 7.4 : CATTLE HERD DISTRIBUTION



Each grid square 5km x 5km. Scale approximately 1 : 350,000.

- |   |                     |   |                              |
|---|---------------------|---|------------------------------|
|  | Major roads.        |  | > 10 herds/10km <sup>2</sup> |
|  | Railway line.       |  | 5 - 9 " "                    |
|  | Rivers and streams. |  | 1 - 4 " "                    |
|  | Lakes.              |  | < 1 " "                      |

### 7.3.2 Cattle Herds.

The number of cattle herds within the survey zone was estimated to be 506 (+/-13% SE), or approximately one herd per five square kilometers (0.22 herds per square kilometer). Figure 7.4 shows the pattern of herd distribution.

### 7.3.3 Herd Size.

Eighty-one cattle herds were recorded during the sample survey. The histogram in figure 7.5 shows the frequency distribution of herd sizes. The mean was 75 animals per herd. This value however, exaggerated the number of animals in a typical herd because it included six large herds, each with more than 200 head. The modal herd size was between 20 and 40 head.

### 7.4. Multivariate Analysis.

In an attempt to elucidate the relationships between cattle distribution and vegetation/land use parameters, and to suggest possible explanations for the observed distribution of cattle, a series of multivariate analyses was performed by computer, using programmes available in the Statistical Package for the Social Sciences (SPSS, 1982). Marriott (1974) has described the principles of the various analyses carried out.

In the first instance, correlation coefficients were calculated for each pair of variables. The resultant correlation matrix is given in table 7.2. Eight pairs of variables were found to be significantly correlated:

FIGURE 7.5 : HERD SIZE FREQUENCY

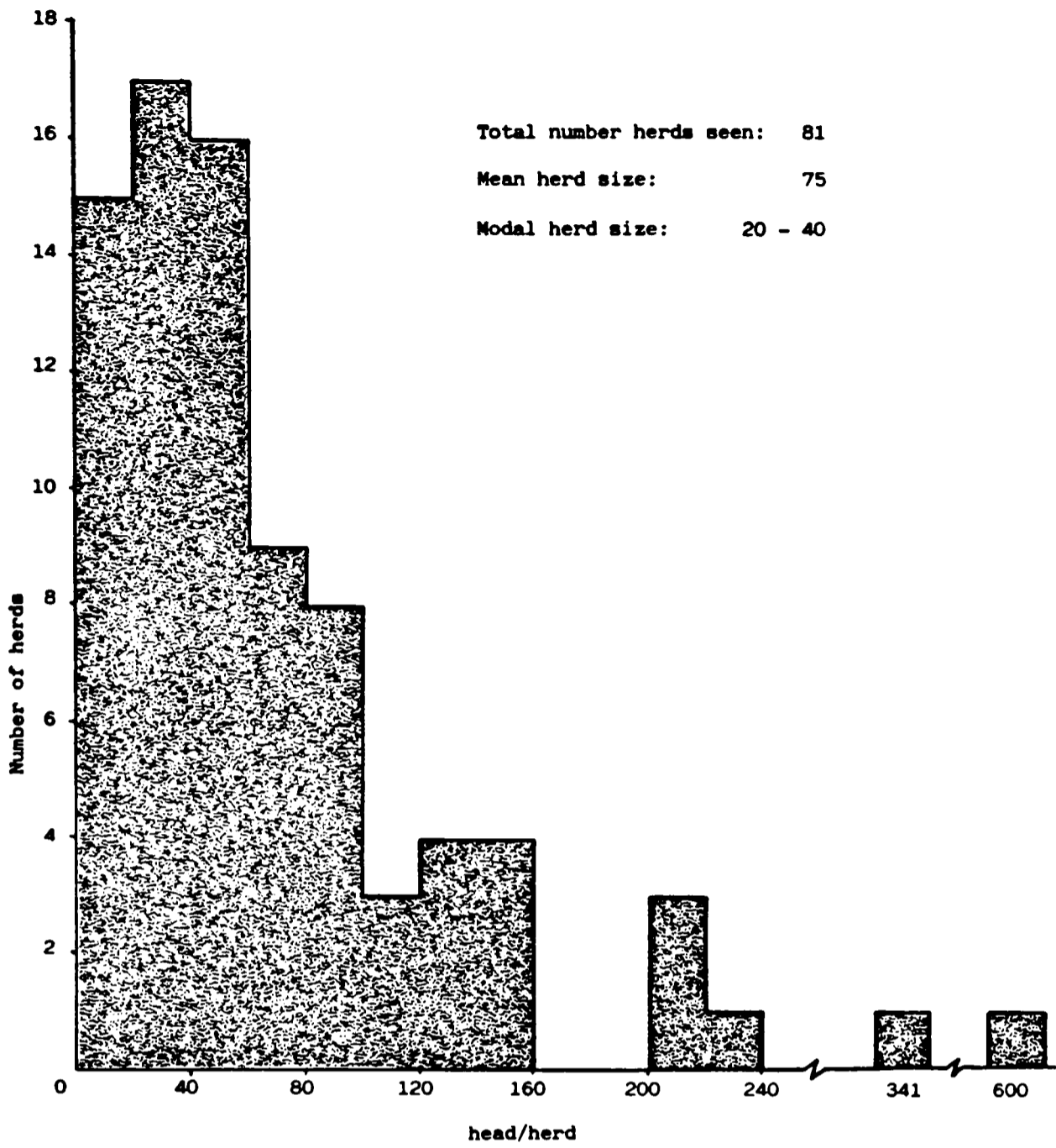
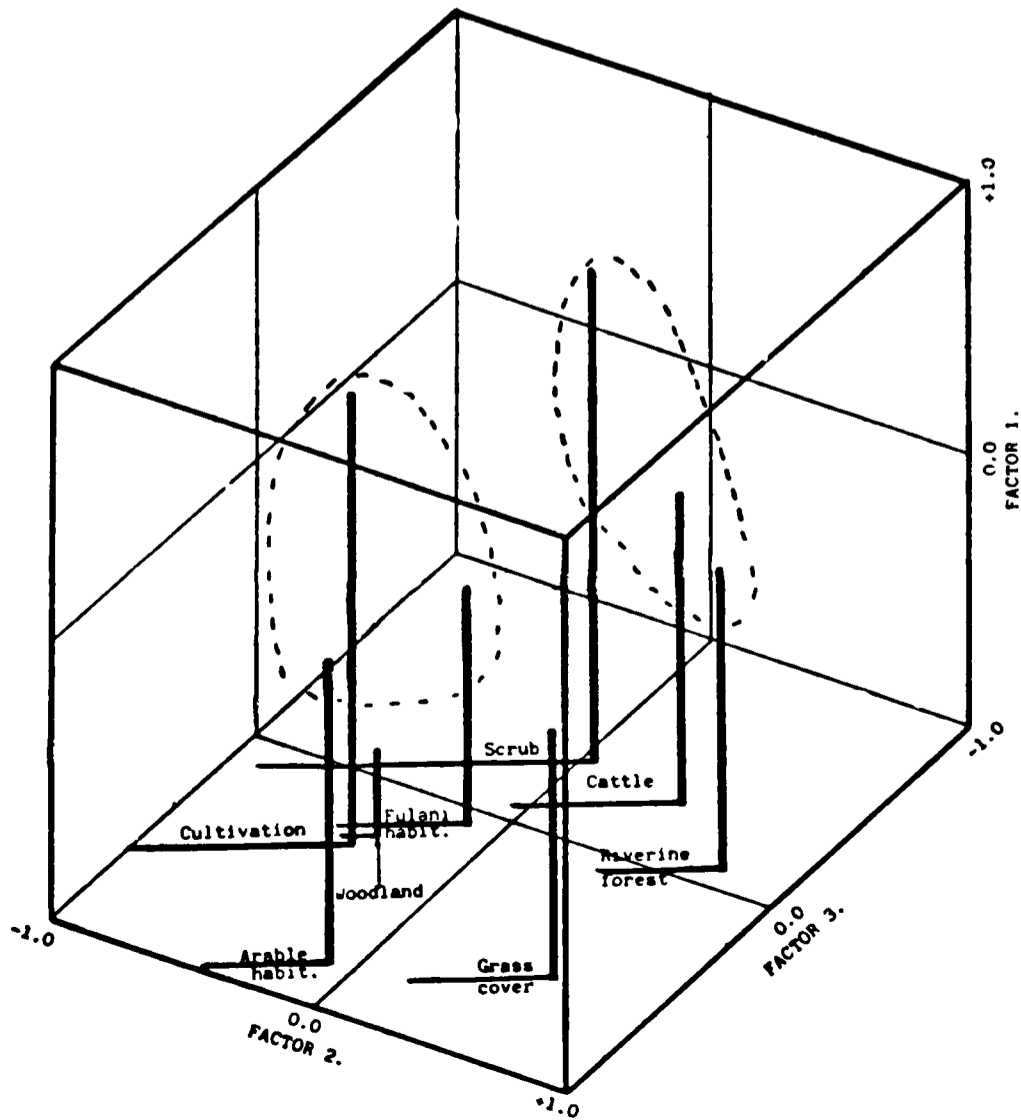


FIGURE 7.6 : Three-dimensional representation of the degree of similarity of variable occurrence in aerial survey grids, as revealed by Principal Components Analysis; showing: sorted, rotated factor loadings. Dashed enclosures indicate suggested groupings of associated variable.



Of the seven variables considered, only riverine forest was positively correlated with cattle.

As might have been expected, arable farmer habitation was positively correlated with cultivation.

Grass cover was negatively correlated with both woodland and riverine forest.

Woodland distribution was negatively correlated with scrub, cultivation and riverine forest.

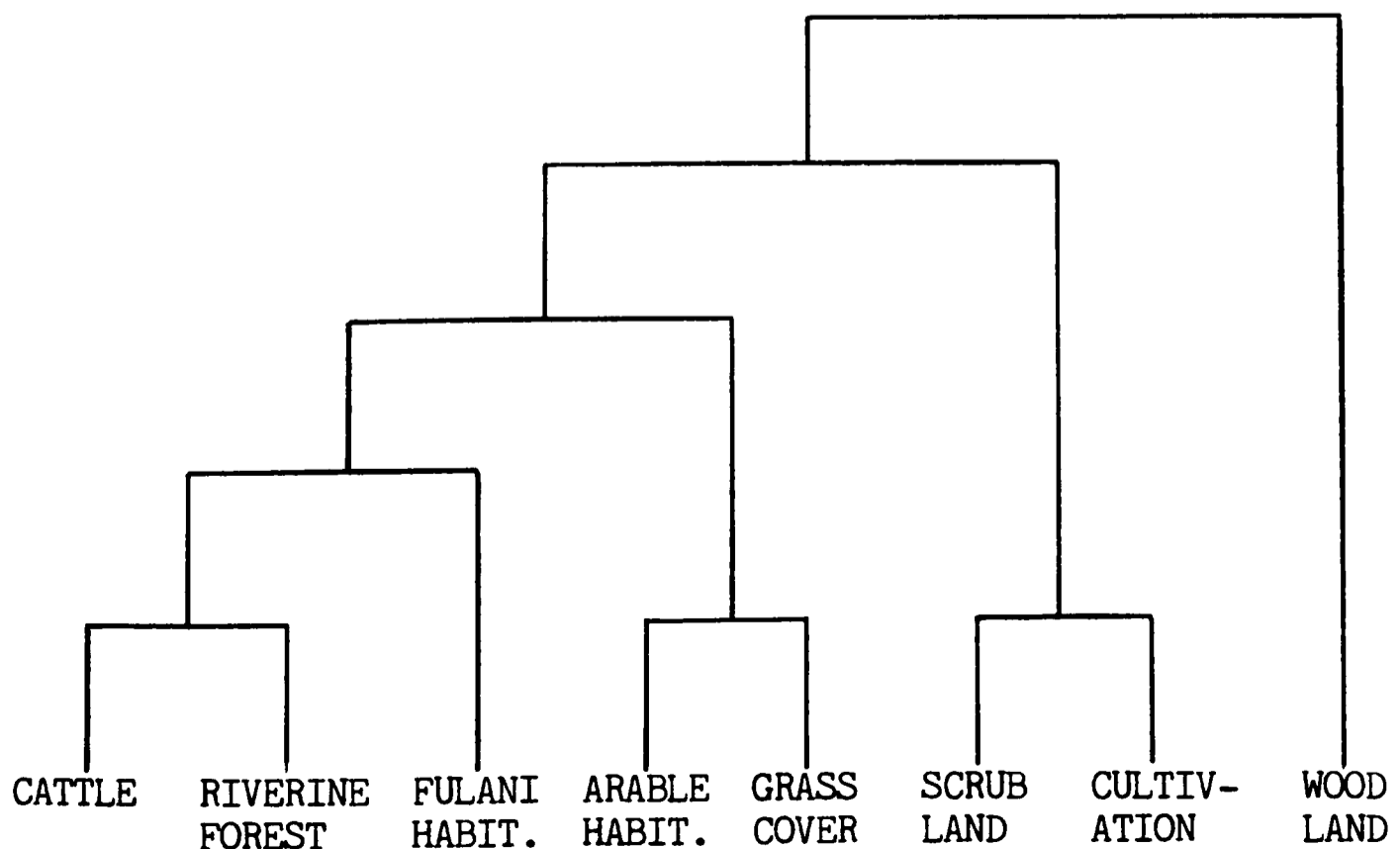
Scrubland was positively correlated with cultivation.

"Principal components analysis" of the variable correlation matrix suggested two possible groupings of associated variables (see figure 7.6):

Cultivation, arable farmer habitation and Fulani habitation.

Cattle, riverine forest and scrubland.

"Cluster analysis", which grouped the variables on the basis of the similarity of their correlation coefficients, suggested the following association of variables:



Thus the distribution of cattle was again found to be most closely associated with riverine forest vegetation; this pair of variables was associated with Fulani habitation; these three variables were associated with the pair of variables: arable habitation and grass cover; these five variables were associated with the variable pair: scrubland and cultivation; and finally the preceding seven variables were linked with woodland.

Finally, a "stepwise multiple regression analysis" was performed, with cattle as the dependent variable. This indicated that significant positive correlations existed between cattle distribution and, in descending order of importance: extent of riverine forest, scrubland, and uncultivated land. However, the proportion of total variance of cattle numbers explained by these three variables was less than 10% (6%, 2% and 1% respectively for each of the added variables).

#### 7.5 Assessment.

38,000 head of cattle were estimated to be within the BICOT project area during the dry season, at an average density of 16.4 animals per square kilometer. This value falls within the dry season density range for other aerial survey zones in Nigeria (see figure 7.7 and table 7.3), which gave estimates between 6.6 and 37.4 head per square kilometer.

Traditionally the cattle population in the BICOT project area would be expected to decrease in the wet season, as the herds moved seasonally northwards onto the Jos plateau; whether such a trend continues to be



shown, remains to be determined by a second aerial survey. However, as can be seen from table 7.3, cattle population within the neighbouring Lafia SE survey zone dramatically increased between dry and wet season.

A survey of Lafia Fulani herdsmen, carried out by questionnaire during the wet season (Bourn, 1979; summarised in appendix 4), indicated that a high proportion had moved into the Lafia area from the north in 1969 and 1974, during and following the Sahel drought, and had since decided to stay. Although most respondents moved their cattle from wet to dry season grazing areas, the distances involved were not great (66% moving less than 60 kilometers), and the majority of these said that their dry season grazing areas were further to the south.

As for the dry season cattle distribution described here, multivariate analyses indicated that it was most closely associated with that of riverine forest. Considering the distribution and abundance of tsetse in the area, described in chapter 6, this is perhaps a surprising result.

However, in explanation it is suggested that riverine forest, as well as being a prime tsetse habitat, is also an indicator of moister soil conditions and the presence of water. At the end of the dry season, Fulani herd management was bound to favour those areas where drinking water and green forage was available, which would lead their cattle into the neighbourhood of riverine forests. If this increased the risk of tsetse and trypanosomiasis challenge, then it must be concluded that it was an acceptable risk, and one which the Fulani were prepared to take.

A dendritic pattern of drainage and associated riverine vegetation divides the BICOT project area into a series of uplands, characterised by a mosaic of farm-, grass-, scrub- and woodland, potentially suitable for cattle grazing. In places, the riverine forests were up to a kilometer wide, whilst in others, the riverine vegetation was as little as 10 to 20 meters in width. In the latter case the banks of water courses were often steep and four to five meters high. Thus wide and narrow riverine vegetation formed an obstacle to the free passage of people and livestock; and their movements were therefore channeled to specific crossing points.

The ecotone between riverine and upland vegetation represented the interface between tsetse and their major hosts. More particularly, forest crossings and watering points frequently used by cattle and man were the major contact points. It was at these sites that the greatest concentrations of tsetse were found; and where, presumably, challenge was highest and the bulk of trypanosomiasis transmission took place.

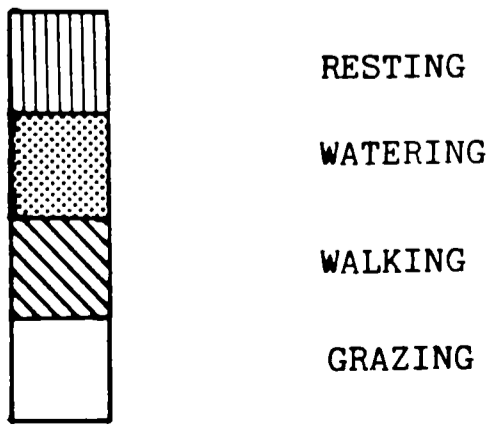
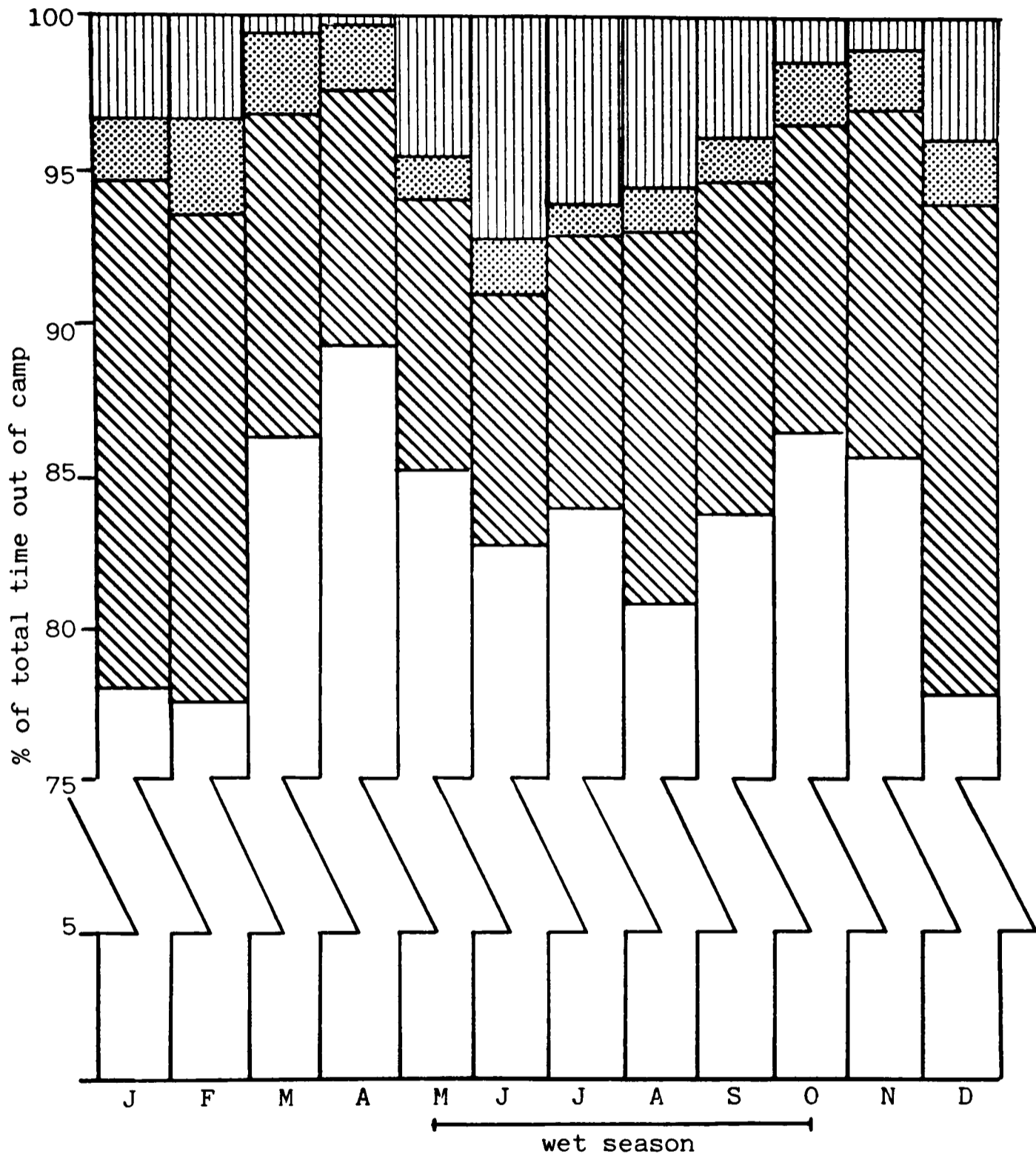
Whilst it is acknowledged that cattle, grazing in the vicinity of the riverine forest ecotone, away from crossing points, may also experience some tsetse challenge, it is argued that their irregular passage along ecotones in search of grazing, is unlikely to sustain large numbers of tsetse. In order to establish a substantial population, tsetse must be able to feed regularly and reproduce over a prolonged period, the generation time being in the order of seven to eight weeks. A reliable and readily available host is therefore required. This role would, under natural conditions, be filled by wildlife species with limited home ranges (e.g bushbuck, monitor lizard and forest pig). In their absence or relative scarcity, it

seems highly probable that one or more semi-permanently resident herds of cattle, frequently crossing from upland to upland or regularly visiting a watering point, are likely to perform the same function.

An interesting indication of how traditional herd management practices tend to minimise the risk of tsetse challenge has been revealed by Bayer and Otchere's (1982) study of the daily activity of Fulani herds (see figure 7.8). Over the course of a year they regularly followed 14 herds, of between 15 and 80 head of cattle, owned by settled pastoralists in the Zonkwa area, and monitored their activity in terms of the amount of time spent walking, grazing, watering and resting. Zonkwa lies to the west of the Jos plateau, about 150 kilometers south of Kaduna, on the boundary between the northern and southern Guinea vegetation zones, with a riverine vegetation and a G. palpalis population similar to those of the BICOT project area, somewhat further to the south.

After overnight corralling at upland homesteads, the cattle were taken out to graze at between 0730 and 1000 hours, depending on season, and were away for 6.5 to 10 hours per day; longer periods being spent during the dry season when food was scarce. Consumption of crop residues occupied a substantial proportion of daily activity during the early dry season, but with their declining availability, grazing on post-burn green flush increased, as did the proportion of browsing.

FIGURE 7.8 : FULANI HERD ACTIVITY  
( AFTER BAYER AND OTCHERE, 1982 )



The period of time spent watering was very short, ranging from a mean minimum of five minutes per day in the wet season, to a mean maximum of 15 minutes per day in the dry season. Shorter periods being spent during the wet season, presumably because water content of the food intake was higher. Over the year, the time spent watering amounted to only 1.7% of the herds normal period of daily activity. Thus it would appear, that under traditional herd management practices and in conditions prevailing around Zonkwa, or within the BICOT project area, the duration of time in which cattle were likely to experience significant tsetse challenge was extremely limited, representing on average less than 1% of any 24 hour period.

## 8 DISCUSSION AND CONCLUSIONS.

The control of trypanosomiasis in Nigeria has been a long-standing government aim, which has been given high priority. As outlined in chapter 2, government organised disease control programmes can be divided into three phases:

1930 to 1960, a period when control of human sleeping sickness was of primary importance to the medical authorities. Massive surveillance and case treatment programmes were carried out, in conjunction with vector control operations. Initially the latter were largely dependent on the clearance of vegetation, but subsequently they came to rely on the application of insecticide.

1950 to 1960, a period, following a gradual decline in the importance of rinderpest, and the introduction of new trypanocidal drugs, in which the control of trypanosomiasis became a major priority for the veterinary authorities and cattle treatment figures rose dramatically.

1955 to 1975, a period in which veterinary authorities placed increasing emphasis on vector control through ground application of insecticide, as a means, both of controlling the disease, and increasing the amount of grazing land available. During the course of what became known as the tsetse eradication programme, an account of which is given in chapter 3, tsetse were eliminated from an extensive region of north-eastern Nigeria.

Today, neither human nor animal trypanosomiasis are as important as they once were, and they no longer constitute such a serious disease problem as they did in the past. The prevalence of sleeping sickness has declined from a peak value of some 20% of the sampled population at the height of the epidemic in 1935, to less than 1/10,000 in 1976, although a few small endemic foci of infection still persist. Comparable figures for animal trypanosomiasis in Nigeria's cattle population do not exist, but the prevalence of detected cases in animals brought for treatment seems to have declined. There has been a 75% reduction in the number of cattle treatments given over the period from 1957 to 1974, and there has been a tendency for less severe, more chronic forms of the disease to prevail (Putt et al., 1980).

Whilst government trypanosomiasis control programmes must have contributed to the general decline of the disease, and have been comparatively well reported, they have not operated in isolation. Other factors, which have not been so well documented, have played a very significant and perhaps more important role. An attempt has been made in this thesis to explore the wider environmental context within which government control programmes have been mounted. A key concept, which has been emphasised in the preceding chapters, is that the Nigerian environment has been undergoing a long and continuing process of change, brought about by the activities of her large, expanding and predominately rural population.

#### 8.1 Agricultural Expansion and Environmental Change.

Over the past fifty years the number of Nigerians has almost certainly increased three or four fold, and the extent and intensity of both farming and hunting have increased commensurately. The net effect of these spontaneous man-induced changes of the environment, has been a widespread reduction in tsetse habitats and wildlife hosts, which has inevitably led to an overall decline in the abundance and distribution of tsetse populations.

Documented changes in tsetse distribution have been examined in chapter 4. Whilst records are scanty, referring primarily to changes in the distribution of G. morsitans, for which both advances and recessions have been observed, the available information indicates a trend of long term decline, leading to the disappearance of this species in many areas, both within the tsetse eradication zone prior to initiation of vector control operations, and more generally outside

the eradication zone. There is also some evidence of the disappearance of populations of G. palpalis in the northern part of their range following increased human activity (Onyiah, 1978), but both G. palpalis and G. tachinoides have been reported in peridomestic habitats further south (Baldry, 1969a). The paucity of documentary evidence for declining tsetse distribution is probably more a reflection of the unrewarding nature of such scientific studies, rather than an indication of the actual extent and significance of its occurrence.

It has long been recognised that the distribution of G. morsitans is limited by the activities of human population. Nash (1948) delineated the boundaries of G. morsitans belts on the basis of human population distribution as indicated by the 1931 census. The reliability of that and subsequent censuses may be questioned, and the present day pattern of human distribution is most uncertain.

Recently produced vegetation and land use maps derived from various remote sensing techniques, examined in chapter 5, are considered to give a much better, and more direct indication of the degree to which the Nigerian environment has been modified by human activity.

Such maps, however, and the imagery from which they are produced, reflect conditions at fixed points in time, and do not indicate the rates at which changes have taken place. By comparative interpretation of aerial photographs, taken many years apart, it was possible to analyse the changes in vegetation and land use that had occurred in two areas: Azare within, and Lafia outside, the tsetse eradication zone. Both had experienced similar high rates of agricultural

expansion, which matched the rates of human population growth. Cultivation was found to have increased at the expense of upland woodlands and grasslands. Cattle populations in both regions had also increased, and appeared to have done so at a slightly faster rate in the Lafia area, which had not been reached by the tsetse eradication programme.

In the north-eastern part of the Lafia area, where land use intensity was high and human population density was estimated to in the region of 70 to 80 people per square kilometer, extensive deforestation of riverine vegetation had recently taken place, and was in progress during the course of tsetse surveys described in chapter 6.

In the past, both G. morsitans and G. longipalpis had been recorded in this area, but neither of these savanna species, which are largely dependent on game animals, remained, except within the confines of Pandam Wildlife Park where G. longipalpis persisted. Despite extensive cultivation and deforestation, however, and in the virtual absence of wildlife, G. palpalis and G. tachinoides were still to be found. G. palpalis was by far the commonest species caught, but its distribution was limited to riverine vegetation, which amounted to only some 5% of the land area, with concentrations occurring at riverine forest crossing and watering points, particularly those frequented by cattle.

Mark-release-recapture and removal trapping estimates indicated that G. palpalis population levels were low, ranging from 2 to 20 males and 2 to 40 females per hectare of riverine forest, with higher densities occurring in larger habitats. Taking into consideration the

small proportion of total land area actually occupied by riverine forest, the overall density of G. palpalis was estimated to be in the region of 10 to 100 males and 10 to 200 females per square kilometer.

A low altitude aerial survey at the end of the dry season, described in chapter 7, indicated that there were some 38,000 head of cattle in the area, at a density of 16 animals per square kilometer, and that their distribution was associated with that of riverine vegetation. A wet season survey of cattle population distribution and abundance has yet to be carried out, but from ground observations and the responses to a questionnaire of Fulani stock owners (appendix 4) it was evident that a high proportion of the cattle were resident in the general area all year round.

In the virtual absence of wildlife and with the abundance of cattle, and in view of the concentration of G. palpalis populations around cattle crossing points, it is hard to escape the conclusion that the survival of G. palpalis was largely dependent on the presence of cattle. Certainly, G. palpalis were commonly seen to feed on them.

As mentioned in chapter 7, however, Fulani herd management practices greatly restricted the duration of close contact between cattle and tsetse, which was limited to a period of 5 to 15 minutes a day, depending on season, when cattle were taken to water, or crossed from one upland grazing area to another.

Thus, with the relatively small size of G. palpalis populations, their limited distribution, and their low trypanosome infection rates (less than 5%, see appendix 2) cattle in the Lafia area were likely to experience very low levels of trypanosome challenge.

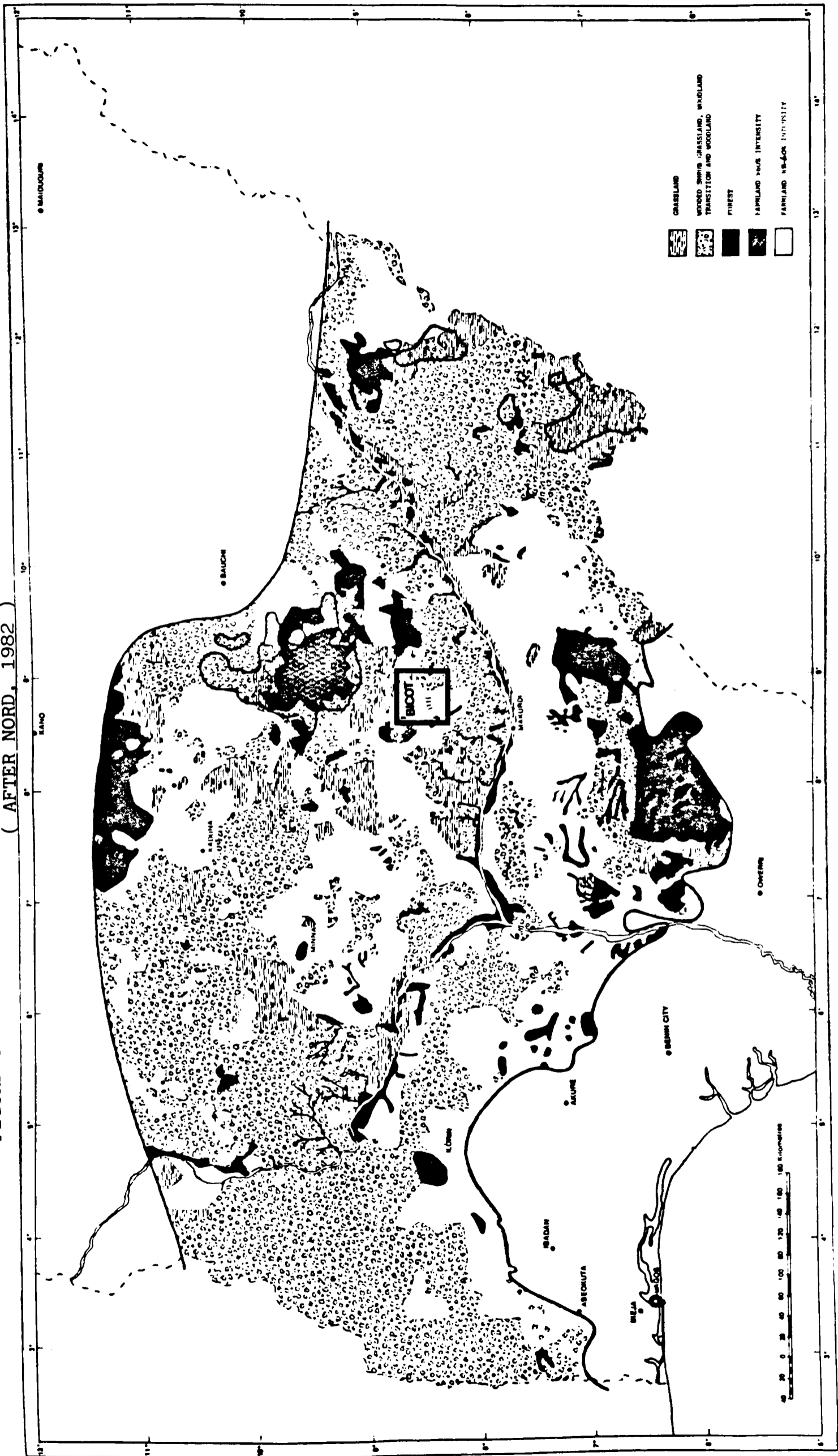
The following description could well apply to the Lafia region:

"That Fulani cattle live and breed, apparently in perfect health, in districts in which G. palpalis and G. tachinoides are widely distributed is undoubtedly true, indeed it is an everyday occurrence to see herds of cattle grazing beside streams, at the very spots where tsetse have been found to be most numerous."

The quotation in fact refers to Ilorin province, at the same latitude as Lafia, but to the west of the Niger river, and was written seventy years ago by Macfie (1913). During the intervening period, as a result of environmental changes brought about by the activities of an increasing human population, agricultural expansion and prolonged hunting, the conditions described by Macfie around Ilorin, and those currently prevailing in the Lafia region, have become far more widespread.

Although the area to the north-east of Lafia, described in chapters 6 and 7, only occupied some 2,500 square kilometers of land, and thus covered only a small proportion of the total sub humid zone, it nevertheless may be considered representative of a much larger area, which has been substantially modified by human activity. As indicated in figure 8.1, areas of medium to high intensity farmland occupy some 30% to 40% of the zone.

FIGURE 8.1 : VEGETATION AND LAND USE IN THE NIGERIAN SUB-HUMID ZONE  
( AFTER NORD, 1982 )



## 8.2 Changing Nature of the Disease.

It seems reasonable to assume, as Ford (1971) has suggested, that the various trypanosomiases originated as zoonoses, in which wildlife hosts, tsetse vectors and trypanosomes co-evolved with each other and developed adaptive mechanisms of co-existence. One can envisage a wildlife reservoir of trypanosomes perpetuated in a "sylvatic cycle" (MacLennan, 1974). The introduction of novel hosts, such as man or livestock, into this system; the transfer of trypanosome strains from one region to another; or the removal or reduction of key components; are bound to disturb the established zoonotic equilibrium between hosts, vectors and trypanosomes.

Initially, when inexperienced hosts are challenged by trypanosomes, or when experienced hosts are challenged by newly introduced strains of trypanosome to which they are not adapted, the resultant infection in susceptible individuals is likely to be severe and acute (Fiennes, 1971).

Over time, however, if the changes affected are permanent, the disease system will adjust. There will be strong selection on host species to develop tolerance or resistance to infection, and trypanosome species will become less virulent and less pathogenic. Failure to do so would otherwise lead to host death and disappearance of the causative strain of trypanosome.

Duggan (1962) has suggested that the 1930s sleeping sickness epidemic was an indirect result of Pax Britannica, the establishment of an extensive communication network, and the resultant increased movement

of the human population. Thus, individuals who had previously lived outside the endemic zones came into contact with trypanosomes for the first time, and new strains of trypanosome were transferred from endemic areas by human carriers.

Ford (1971) has linked the epidemic to the recovery of wildlife and cattle populations, following the rinderpest epizootic of the late nineteenth and early twentieth centuries. He suggested that this would effectively have, both increased the wildlife reservoir of trypanosomes, and by the greater seasonal movement of nomadic cattle, encouraged the transfer of trypanosomes from the sylvatic cycle dominated by G. morsitans, to G. palpalis and G. tachinoides in riverine habitats. Thus human populations, dependent on water supplies from these habitats, would have come into indirect but closer contact with trypanosomes from the wildlife reservoir, to which they were not adapted.

MacLennan (1970 and 1974) emphasised the greater risk and challenge that G. morsitans populations represent to cattle, partly because of their higher infection rates, but also because the trypanosomes transmitted were more likely to have been derived from game animals, and therefore not adapted to cattle. The G. morsitans advances recorded in the 1950s, and mentioned in chapter 4, must have brought cattle into closer contact with the sylvatic cycle. Certainly their expansion coincided with a dramatic rise in the number of cattle treatments (figure 8.3).

Since that time, as already mentioned, the fragmented distribution of G. morsitans has receded still further (figure 4.1), and the number of cattle treatments has fallen dramatically.

Another important factor, which has influenced the nature of the disease, is the process of Fulani sedenterisation which has been taking place for many years (Tiffin, 1976; and Oxby, 1982). The conventional view of the transhumant Fulani, moving with their cattle from northern tsetse free areas into more southerly tsetse infested regions in the dry season, and back again in the wet season, no longer seems to be typical, or generally valid. ILCA (1979) has estimated that only 20% of Fulani can be regarded as "nomadic", with 50% leading a "semi-settled" and 30% a "settled" existence.

Recent wet and dry season aerial surveys of the distribution and abundance of cattle in the sub-humid zone have indicated a close association between cattle and cultivation. Milligan, Bourn and Chachu (1979) have suggested that this reflects an interdependence between Fulani livestock owners and arable farmers, in terms of utilisation of crop residues; manuring of fields; and marketing of dairy produce. Inevitably social "conflicts" have arisen between the two (van Raay, 1975) but these might better be regarded as a sign of dynamic interaction between mutually dependent members of a community.

With the gradual expansion of agriculture into the sub-humid zone, one might expect an associated change in overall cattle distribution. Although the information available is not the most reliable, Putt et al. (1980) have shown that there has been a tendency for Jangali cattle tax returns to decline in the north of the country and increase further south within the zone. Certainly Zebu cattle are now found well beyond the southern limit of their range as indicated by Nash (1948).

Thus in epidemiological and epizootiological terms, the widespread changes in the Nigerian environment, brought about by the progressive increase in human population and agricultural expansion, can be seen to have led to an overall shift in the balance of relationships between tsetse, trypanosomes, wildlife, people and cattle.

Hunting has greatly reduced, and locally led to elimination of game populations. As a result, the wildlife reservoir of trypanosomes, the savanna species of tsetse, and the significance of the high challenge sylvatic cycle of trypanosomiasis transmission, have all declined, and in many areas ceased to exist. G. palpalis and G. tachinoides populations, with their relatively low infection rates, however, have tended to persist usually in very restricted habitats, as typified by the BICOT project area, where infection rates were less than 5%. In the absence of wildlife and with their more catholic feeding habits, riverine tsetse have become orientated to livestock and human hosts. A low challenge non-sylvatic trypanosomiasis transmission cycle has tended to predominate, which has favoured the development of appropriate immune responses in host species, and the selection of less virulent, and less pathogenic strains of trypanosomes. This process has been further encouraged by the trend of Fulani and their cattle to become more sedenterised, which has reduced their contact with the sylvatic cycle and limited the transfer of trypanosome strains from one region to another.

This situation is in marked contrast to the circumstances on the Jebba-Ilorin-Oyo cattle route (Jordan, 1965b; Baldry, 1969; Riordan, 1976), where exceptionally high infection rates (45% to 77%) were found in G. morsitans feeding exclusively on cattle. Tsetse

infection rates are greatly influenced by the infection rate and species of their host (Jordan, 1965a). Trade cattle generally show a high incidence of trypanosomiasis, either as a result of the stressful conditions of their journey, which makes them more susceptible to infection, or because during their travel they are challenged by novel trypanosome strains, to which their immune systems are not adapted. Thus tsetse feeding on them have a greater chance of becoming infected. In the BICOT project area, however, many cattle were resident all year round. Their immune systems would therefore be better adapted to local trypanosome strains, and their general plane of nutrition would be higher than that of trade cattle.

### 8.3 Influence of Climate ?

So far, emphasis has been placed on human activity as the agent for environmental change in Nigeria, which, together with government organised disease control programmes, has led to an overall decline in tsetse populations, and a fundamental shift in the epidemiology/epizootiology of trypanosomiasis. In addition to these human influences, it may be of more than passing interest and coincidence to note a correspondence between climatic changes, and major events in the history of tsetse and trypanosomiasis control.

Bunting et al. (1976) have examined meteorological records for evidence of long term changes in rainfall in the West African Sahel. The stations selected, with long data series (1905 to 1974), were all located on the southern boundary of the Sahel, or in the Sudan zone: Kano, Maiduguri, Niamey, Sokoto and Zinder.

Records from these stations may just as well be taken as a reflection of rainfall trends in the Sudan zone of northern Nigeria. It was in this zone that the sleeping sickness epidemic was first recognised; where the second Lake Chad epidemic took place; where major G. morsitans advances and recessions were reported; and where the tsetse eradication programme reclaimed most land.

Marked fluctuations in annual rainfall are characteristic of the zone, and the amount of rainfall may be considered to be inversely related to the severity of the climate for a particular year. Although Bunting et al. (1976) failed to find any statistically significant evidence for rainfall to have increased or decreased in the long term, their zonal records clearly indicate a tendency, in the short term, for annual rainfall to progressively increase or decrease in successive years (figure 8.2).

The period from 1926 to 1931 was one characterised by increasing annual rainfall, which corresponded with the time immediately prior to the sleeping sickness epidemic, when there was an increasing awareness of the importance of human trypanosomiasis. Was this perhaps a period of G. morsitans advance, and increased human contact with the sylvatic cycle ?

With the exception of 1945, the period from 1935 to 1949 was one of generally declining annual rainfall, and corresponded with a marked decline in the number of sleeping sickness cases treated (indicated by dots in figure 8.3). Was this perhaps a period of G. morsitans recession and reduced contact with the sylvatic cycle ?

FIGURE 8.2 : LONG TERM FLUCTUATIONS IN MEAN ANNUAL RAINFALL FOR KANO, MAIDUGURI, NIAMEY, SOKOTO AND ZINDER ( AFTER BUNTING ET AL., 1976 )

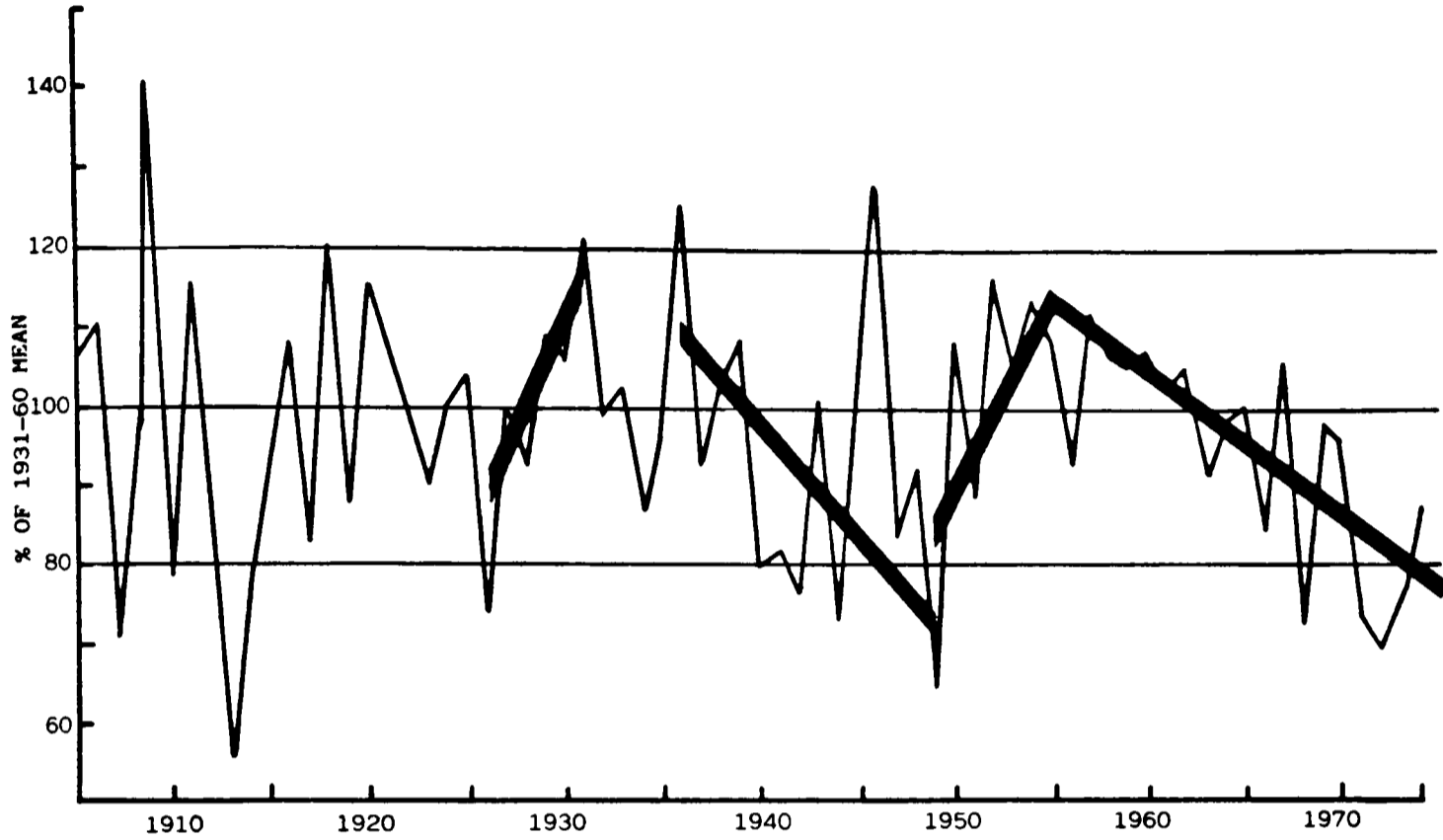
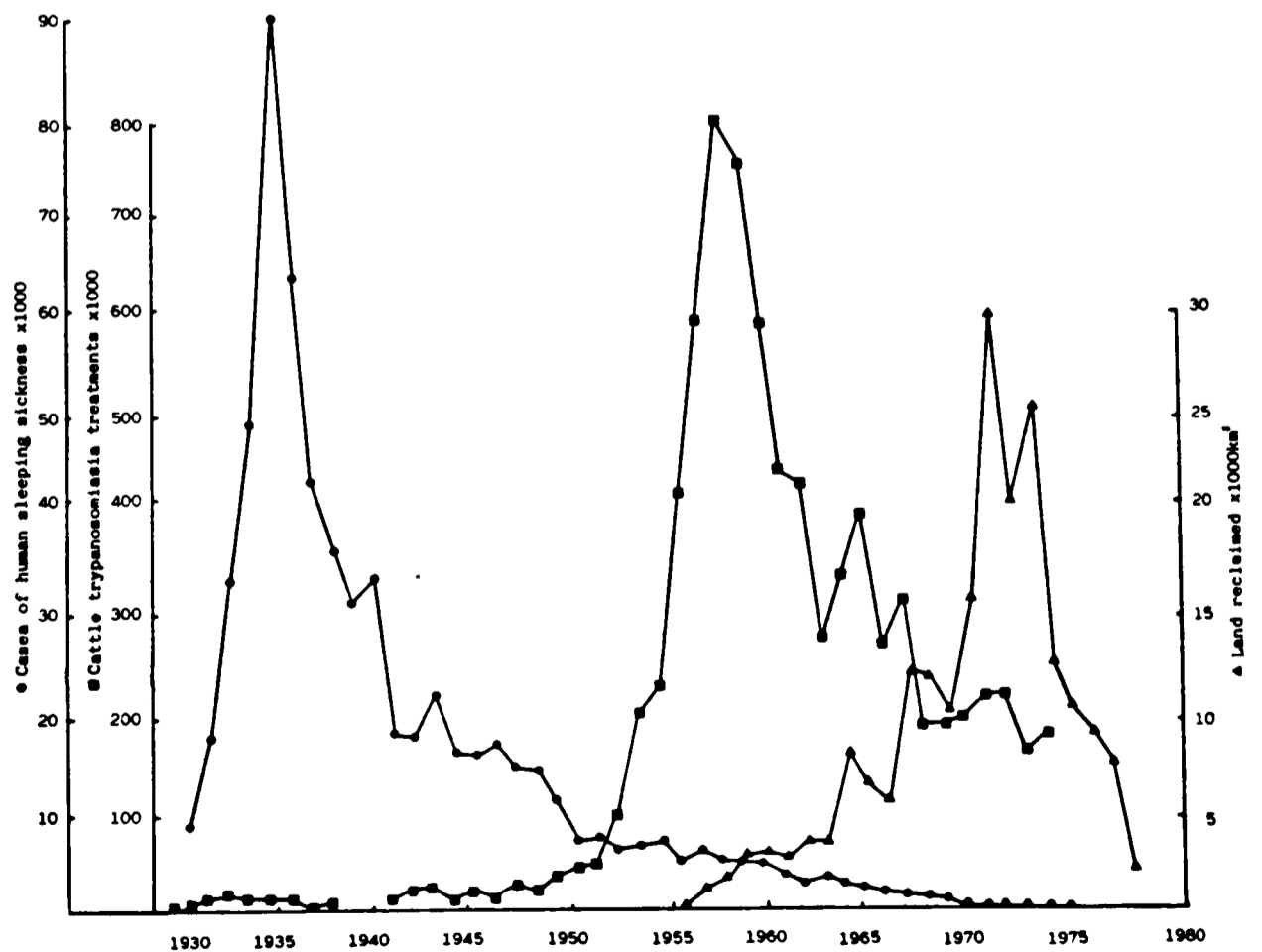


FIGURE 8.3 : SLEEPING SICKNESS CASES, CATTLE TRYPANOSOMIASIS TREATMENTS AND LAND RECLAIMED DURING TSETSE ERADICATION PROGRAMME ( SAME TIME SCALE AS FIGURE 8.2 )



The period from 1949 to 1955, was one of generally increasing annual rainfall, which corresponded with the second Lake Chad sleeping sickness epidemic (figure 2.2). It was also a period when numerous advances in G. morsitans belts were reported, and one in which the number of cattle treated for trypanosomiasis greatly increased (indicated by squares in figure 8.3).

The period from 1955 to 1974 was one of gradually declining rainfall, leading to the Sahel drought. It corresponded with the widespread decline of G. morsitans, major progress in the tsetse eradication programme (indicated by triangles in figure 8.3), and reduced demand for trypanosomiasis treatments.

In the northern part of Nigeria tsetse are at the limits of their range and are thus likely to be susceptible to climatic fluctuations such as those mentioned above. However, further to the south where climatic conditions are less extreme, tsetse populations are less prone to the vagaries of climate.

GENERAL BIBLIOGRAPHY.

History.

AJAYI, J. F. A., and M. CROWDER, 1974. History of West Africa. Longman, London.

CROWDER, M. 1978. The Story of Nigeria. Faber and Faber. London.

Geography.

BARBOUR, K. M., J. S. OGUNTOYINBO, O. C. ONYEMELUKWE and J. C. NWAFOR, 1982. Nigeria in Maps. Hodder and Stoughton, London.

BUCHANAN, K. M. and J. C. PUGH, 1955. Land and People in Nigeria. The Human Geography of Nigeria and its Environmental Background. University of London Press.

HARRISON CHURCH, R. J., 1980. West Africa: A Study of the Environment and Man's Use of it. Longman, London.

OGUNTOYINBO, J. S., O. O. AREOLA and M. FILANI 1978. A Geography of Nigerian Development. Heinemann, Ibadan.

UDO, R. K., 1970. Geographical Regions of Nigeria. Heinemann, London.

Climatology.

KOWAL, J. M. and D. KNABE, 1972. An Agroclimatological Atlas of the Northern States of Nigeria. Ahmadu Bello University Press, Samaru-Zaria.

OJO, O., 1977. The Climates of West Africa. Heinemann, London.

Agricultural Ecology.

AGBOOLA, S. A., 1979. An Agricultural Atlas of Nigeria. Oxford University Press.

AJAEGBU, H. I., 1976. Urban and Rural Development in Nigeria. Heinemann, London.

AHN, P. M., 1974. West African Soils. Oxford University Press.

IRVINE, F. R., 1974. West African Crops. Oxford University Press.

KOWAL, J. M. and A. H. KASSAM, 1978. Agricultural Ecology of Savanna: A Study of West Africa. Clarendon Press, Oxford.

OYENUGA, V. A., 1967. Agriculture in Nigeria. Food and Agriculture Organisation of the United Nations, Rome.

Animal Husbandry.

FRICKE, W., 1979. Cattle Husbandry in Nigeria. Heidelberg Univeristy Press.

ILCA, 1979. Livestock Production in Sub-humid Zone of West Africa: A Regional Review. System Study 2. International Livestock Centre for Africa, Addis Ababa.

LOOSLI, J. K., V. A. OYENUGA and G. M. BABATUNDE, 1974. Animal Production in the Tropics. Heinemann, Ibadan.

Sociology.

ST. CROIX, F. W. DE, 1945. The Fulani of Northern Nigeria. Government Printer, Lagos.

STENNING, D. J., 1957. Transhumance, migratory drift, migration. Patterns of pastoral Fulani nomadism. Journal of the Royal Anthropological Institute, 87 57-73.

TIFFIN, M., 1976. The Enterprising Peasant: Economic Development in Gombe Emirate, North-Eastern Nigeria, 1900-1968. Overseas Research Publication No.21. Ministry of Overseas Development, London.

VAN RAAIJ, J. G. T., 1975. Rural Planning in a Savanna Region. Rotterdam University Press.

REFERENCE BIBLIOGRAPHY.

- AFOLAYAN, A. A., 1978. Population. pp 113-123 in: A Geography of Nigerian Development. Edited by J. S. Oguntoyinbo, O. O. Areola and M. Filani. Heinemann, Ibadan.
- AJAEGBU, H. I., 1976. Urban and Rural Development in Nigeria. Heinemann, London.
- AJAYI, J. F. A. and M. CROWDER, 1974. History of West Africa. Longman, London.
- ALLAN, W., 1965. The African Husbandman. Oliver and Boyd, Edinburgh.
- ANON, 1953. Proceedings of a Conference Called to Consider the Report of the Nigerian Livestock Mission. Government Printer, Lagos.
- BAILEY, N. T. J., 1951. On estimating the size of mobile populations from mark-release-recapture data. *Biometrika*, 38 293-306.
- BAKER, J. R., 1970. Techniques for the detection of trypanosome infections. pp 66-88 in: The African Trypanosmiases. Edited by H. W. Mulligan. George Allen and Unwin, London.
- BALDRY, D. A. T., 1964. Observations on a close association between Glossina tachinoides and domestic pigs near Nsukka, Eastern Nigeria. II Ecology and trypanosome infection rates in G. tachinoides. *Ann. trop. Med. Parasit.* 58 32-44.
- BALDRY, D. A. T., 1966. On the distribution of Glossina tachinoides in West Africa. Parts 1 and 2. Eleventh meeting of the International Scientific Committee for Trypanosomiasis Research, Nairobi pp 95-109.
- BALDRY, D. A. T., 1969. Distribution and trypanosome infection rates of Glossina morsitans submorsitans Newst. along a trade cattle route in south-western Nigeria. *Bull. ent. Res.*, 58 537-548.
- BALDRY, D. A. T., 1969a. Variations in the ecology of Glossina spp., with special reference to Nigerian populations of Glossina tachinoides. *Bull. Wld. Hlth. Org.* 40 859-869.
- BALDRY, D. A. T. and A. M. V. van de VLOEDT, 1982. A modified wing-fray analysis technique for age estimation of Glossina. Proceedings of a symposium: Sterile Insect Technique and Radiation in Insect Control. 29 June to 3 July 1981. Neuherrberg. International Atomic Energy Agency, Vienna.
- BAYER, W. and E. O. OTCHERE, 1982. Grazing time of white Fulani cattle kept by settled pastoralists on the Kaduna plains. Report to the International Livestock Centre for Africa, Sub-humid Programme, Kaduna.
- BEGON, M., 1979. Investigating Animal Abundance. Edward Arnold, London.

- BLASDALE, P., 1960. The development of a practical means of eradicating Glossina morsitans submorsitans Newst. and G. tachinoides West in the Sudan savannah zone of Northern Nigeria. Eighth meeting of the International Scientific Committee for Trypanosomiasis Research, Jos. pp 295-302.
- BOHANNAN, L. and P. BOHANNAN, 1953. The Tiv of Central Nigeria. Ethnographic Survey of Africa: West Africa Part 8. International African Institute, London.
- BOURN, D. M., 1979. A survey of Lafia Fulani. Report to the International Livestock Centre for Africa, Sub-humid Programme, Kaduna.
- BOURN, D. M. and M. OLADUNMADE, 1980. Eight areas in Central Nigeria of potential interest for the biological control of Glossina palpalis palpalis using the sterile male release technique. Report to the Federal Department of Pest Control Services, Kaduna, and the joint division of the International Atomic Energy Agency and the Food and Agriculture Organisation, Vienna.
- BOURN, D. M. and K. MILLIGAN, 1982. Aerial survey of cattle, vegetation and land use in a region of the Nigerian sub-humid zone, prior to biological control of tsetse by sterile male release. Report to the Federal Department of Pest Control Services, Kaduna, and the International Livestock Centre for Africa, Sub-humid Programme, Kaduna.
- BRUCE, D., 1895. Preliminary report on the tsetse fly disease or nagana, in Zululand. Bennet and Davie, Durban.
- BRUNT, M. A., 1967. The methods employed by the Directorate of Overseas Surveys in the assessment of land resources. Act. 2e Symp. int. Photo-Interp. Paris. 1966 VI3 - VI10.
- BUCHANNAN, K. M. and J. C. PUGH, 1955. Land and People in Nigeria: The Human Geography of Nigeria and its Environmental Background. University of London Press.
- BUNTING, A. H., M. D. DENNETT, J. ELSTON and J. R. MILFORD, 1976. Rainfall trends in the West African Sahel. Quart. J. R. Met. Soc., 102 59-64.
- BUXTON, P. A. 1955. The Natural History of Tsetse Flies. London School of Hygiene and Tropical Medicine, Memoir No. 10. H. K. Lewis, London.
- CHALLIER, A. AND C. LAVEISSIERE, 1973. Un nouveau piege pour le capture des glossine (Glossina : Diptera, Muscidae): description et essais sur le terrain. Cah. ORSTOM, Ser. Ent. Med. et Parasitol. II, 251-262.
- CLARK, C., 1977. Population Growth and Land Use. Macmillan, London.

- CONWAY, G. R., M. TRPIS and A. H. McCLELLAND, 1974. Population parameters of mosquito Aedes aegypti (L) estimated by mark-release-recapture in a suburban habitat in Tanzania. J. Anim. Ecol., 43 289-304.
- CROWDER, M., 1978. The Story of Nigeria. Faber and Faber, London.
- CUISANCE, D., H. POLITZAR, G. BOURDOISEAU, J. FEVRIER and E. SELLIN, 1979. Efficiency of chemical and mechanical barriers against Glossina palpalis gambiensis. In sixteenth meeting of International Scientific Committee for Trypanosomiasis Research, Yaounde, pp487-492.
- DAHL, G. and A. HJORT, 1976. Having Herds: Pastoral Growth and Household Economy. Stockholm Studies in Social Anthropology. 2. University of Stockholm.
- DAVEY, T. H., 1948. Trypanosomiasis in British West Africa. HMSO, London.
- DAVID WEST, K. B., 1981. Strategy for relocation of the national herd in Nigeria. In: Report of a panel of experts on development aspects of the programme for the control of African animal trypanosomiasis and related development. First session, Lome, Togo. 8 - 12 December 1980. Food and Agriculture Organisation of the United Nations, Rome.
- DAVIES, H., 1964. The eradication of tsetse in the Chad river system of Northern Nigeria. J. Appl. Ecol., 1 387-403.
- DAVIES, H., 1971. Further eradication of tsetse in the Chad and Gongola river systems in North-Eastern Nigeria. J. Appl. Ecol., 8 563-578.
- DAVIES, H., 1977. Tsetse Flies of Nigeria. Oxford University Press, Ibadan.
- DAVIES, H. and P. BLASDALE, 1960. The eradication of Glossina morsitans submorsitans Newstead and Glossina tachinoides Westwood in part of a river flood plain in Northern Nigeria by chemical means, Part III. Bull. ent. Res., 51 265-270.
- DAVIES, J., 1959. An attempt to eradicate Glossina palpalis (R.-D.) and Glossina tachinoides West. from riverine vegetation in Benue Province, Northern Nigeria, by spraying DDT. Bull. ent. Res., 49 427-436.
- DAVIES, J. B., 1960. Dieldrin in the control of Glossina palpalis (R.-D.) in the southern Guinea savannah of Northern Nigeria. Eighth meeting of the International Scientific Committee for Trypanosomiasis Research, Jos, pp 277-289.
- DELANY, M. J. and D. C. D. HAPPOLD, 1979. Ecology of African Mammals. Longman, London.

- DRANSFIELD, R. D., R. BRIGHTWELL, R. ONAH and C. J. OKOLO 1982. Population dynamics of Glossina morsitans submorsitans Newstead and Glossina tachinoides Westwood in sub-Sudan savanna in Northern Nigeria. I. Sampling methodology for adults and seasonal changes in numbers caught in different vegetation types. Bull. ent. Res., 72 175-192.
- DUDGEON, G. H., 1906. Distribution of tsetse fly on the Niger. J. trop. Med., 9 326-328.
- DUGGAN, A. J., 1962. A survey of sleeping sickness in Northern Nigeria from the earliest times to the present day. Trans. R. Soc. Trop. Med. Hyg., 56 439-486.
- EKANEM, I. I., 1972. The 1963 Nigerian Census - A Critical Appraisal. Ethiope. Publishing Corp., Benin.
- FAO, 1966. Agricultural Development in Nigeria. Food and Agriculture Organisation of the United Nations, Rome.
- FAO, 1974. Programme for the control of African animal trypanosomiasis. AGA/TRYP74/1E. Food and Agriculture Organisation of the United Nations, Rome.
- FAO, 1977. Insecticides and application equipment for tsetse control. Animal Production and Health Paper No. 3. Food and Agriculture Organisation of the United Nations, Rome.
- FAO, 1979. The African trypanosomiasis. Animal Health and Production Paper No. 14. Food and Agriculture Organisation of the United Nations, Rome.
- FDF, 1978. Vegetation and Land Use Maps of Nigeria (69). Derived from Side Looking Airborne Radar (SLAR) imagery. Federal Department of Forestry, Lagos.
- FIENNES, R. N.T- W-, 1970. Pathogenesis and pathology of animal trypanosomiasis. pp 729-750 in: The African Trypanosomiasis. Edited by H. W. Mulligan. George Allen and Unwin, London.
- FINELLE, P., 1973a. African animal trypanosomiasis. Part 1. Disease and Chemotherapy. World Animal Review, 7 1-7.
- FINELLE, P., 1973b. African animal trypanosomiasis. Part 2. Chemoprophylaxis and the raising of trypanotolerant livestock. World Animal Review, 8 24-27.
- FINELLE, P., 1974. African animal trypanosomiasis. Part 3. Control of vectors. World Animal Review, 9 39-43.
- FISHER, R. A. and E. B. FORD, 1947. The spread of a gene in natural conditions in a colony of the moth Panaxia dominula. Heredity, London, 1 143-174.
- FORD, J., 1971. The Role of the Trypanosomiasis in African Ecology. A Study of the Tsetse Fly Problem. Clarendon Press.

- FORD, J. AND K. N. KATONDO, 1977 Maps of tsetse fly (Glossina) distribution in Africa, 1973, according to sub-generic groups, on a scale of 1:5,000,000. Bull. Anim. Hlth. Prod. Afr., 25 187-193.
- GLASGOW, J. P., 1963. The Distribution and Abundance of Tsetse. Pergamon Press, Oxford.
- GLOVER, P. E., 1965. The Tsetse Problem in Northern Nigeria. Patwa News Agency, Nairobi.
- GLOVER, P. E. and P. J. AITCHISON, 1966. Tsetse control and land use in Northern Nigeria: a feasibility survey of Area I. Baraka Press, Kaduna.
- GLOVER, P. E. and P. J. AITCHISON, 1970. Some causes of depopulation in Northern Nigeria. The Nigerian Field, 35 12-28.
- GOUDIE, A. S., 1977. Environmental Change. Clarendon Press, Oxford.
- GOUDIE, A. S., 1981. The Human Impact: Man's Role in Environmental Change. Basil Blackwell, Oxford.
- GRIGG, D., 1970. The Harsh Lands: A Study in Agricultural Development. Macmillan, London.
- HOARE, C. A., 1972. The Trypanosomes of Mammals. Blackwell, Oxford.
- HUNTING, 1978. NIRAD Project Interpretation Phase. Final Report. Hunting Technical Services, Borehamwood, Hertfordshire, U.K.
- ILCA, 1979. Livestock Production in the Subhumid Zone of West Africa: A Regional Review. Systems Study 2. International Livestock Centre for Africa, Addis Ababa.
- ILCA, 1980. The abundance and distribution of cattle on the Jos plateau, Nigeria. International Livestock Centre for Africa, Sub-humid Programme, Kaduna.
- JACKSON, C. H. N., 1937. Some new methods in the study of Glossina morsitans. Proc. Zool. Soc. Lond., (1936) 811-896.
- JACKSON, C. H. N., 1939. The analysis of an animal population. J. anim. Ecol., 8 238-246.
- JAHNKE, H. E., 1976. Tsetse Flies and Livestock Development in East Africa: A Study of Environmental Economics. Weltforum Verlag, Munich.
- JOHNSON, W. B., 1918. Annual Medical Report, Northern Provinces, 1918.
- JOHNSON, W. B. and LL. LLOYD 1923. First report of the tsetse fly investigation in the Northern Provinces of Nigeria. Bull. ent. Res., 13 373-397.
- JOLLY, G., 1969. Sampling methods for aerial census of wildlife populations. E. Afr. Agr. For. J., 35 special issue.

- JORDAN, A. M., 1961. An assessment of the economic importance of the tsetse species of southern Nigeria and the southern Cameroons based on their trypanosome infection rates and ecology. *Bull. ent. Res.*, 52 431-441.
- JORDAN, A. M., 1964. Trypanosome infection rates in *Glossina morsitans submorsitans* Newstead in Northern Nigeria. *Bull. ent. Res.*, 55 219-231.
- JORDAN, A. M., 1965a. 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.
- JORDAN, A. M., 1965b. Bovine trypanosomiasis in Nigeria. The tsetse fly challenge to a herd of cattle trekked along a trade-route. *Ann. trop. Med. Parasit.* 59 270-276
- JORDAN, A. M., 1965c. Long-term fluctuations in the numbers of a population of *Glossina palpalis palpalis* (R.-D.): sixteen years observations. Tenth meeting of the International Scientific Committee for Trypanosomiasis Research, Kampala, pp 85-90.
- JORDAN, A. M., 1965d. Observations on the ecology of *Glossina morsitans submorsitans* Newstead in the northern Guinea savannah of Northern Nigeria. *Bull. ent. Res.* 56 1-16.
- JORDAN, A. M., 1974. Recent developments in the ecology and methods of control of tsetse flies, (*Glossina* spp.) (Dipt. Glossinidae) - a review. *Bull. ent. Res.*, 63 361-399.
- JORDAN, A. M., 1979. Trypanosomiasis control and land use in Africa. *Outlook on agriculture*, 10 123-129.
- JORDAN, A. M., F. LEE-JONES and B. WEITZ, 1961. The natural hosts of tsetse flies in the forest belt of Nigeria and the Southern Cameroons. *Ann. trop. Med. Parasit.* 55 167-179.
- JORDAN, A. M., F. LEE-JONES and B. WEITZ, 1962. The natural hosts of tsetse flies in Northern Nigeria. *Ann. trop. Med. Parasit.* 56 430-442.
- KEAY, R. W. J., 1953. *An Outline of Nigerian Vegetation*. Government Printer, Lagos.
- KERNAGHAN, R. J., 1960. Some aspects of the insecticidal control of *Glossina tachinoides* in Northern Nigeria. Eighth meeting of the International Scientific Committee for Trypanosomiasis Research, Jos, pp 285-293.
- KERNAGHAN, R. J., 1961. Insecticidal control of vectors of human trypanosomiasis in Northern Nigeria. *J. trop. Med. Hyg.*, 64 303-309.

- KERNAGHAN, R. J. and J. DAVIES, 1959. Field trials of the control of Glossina palpalis (R.-D.) by obstructive clearing. Bull. ent. Res., 50 449-466.
- KIRKBY, W. W. and P. BLASDALE, 1960. The eradication of Glossina morsitans submorsitans Newstead and Glossina tachinoides Westwood, in part of a river flood plain in Northern Nigeria by chemical means. Part 2. Bull. ent. Res., 51 253-264.
- KOCK, K. and U. SPIELBERGER, 1979. Comparison of hand-nets, biconical traps and an electric trap for sampling Glossina palpalis palpalis (Robineau-Desvoidy) and G. tachinoides Westwood in Nigeria. Bull. ent. Res. 69 243-253.
- KOEMAN, J. H., W. M. J. DEN BOER, A. F. FEITH, H. H. DE OINGH, P. D. SPLEITHOFF, B. K. NA'ISA and U. SPIELBERGER, 1978. Three years observations on side effects of helicopter applications of insecticides used to exterminate Glossina species in Nigeria. Environ. Pollut., 15 31-59.
- KOEMAN, J. H., and J. H. PENNINGS 1970. An orientational survey on the side-effects and environmental distribution of insecticides used in tsetse control in Africa. Bull. env. Contam. Toxicol., 5 164-170
- KOEMAN, J. H., H. D. RIJKSEN, M. SMIES, B. K. NA'ISA and K. J. R. MACLENNAN, 1971. Faunal changes in a swamp habitat in Nigeria sprayed with insecticide to exterminate Glossina. Neth. J. Zool., 21 164-170.
- KOEMAN, J. H., and W. TAKKEN, 1978. The environmental impact of tsetse control operations. Food and Agriculture Organisation of the United Nations, Rome.
- KOWAL, J. M. and D. KNABE, 1972. An Agroclimatological Atlas of the Northern States of Nigeria. Ahmadu Bello University Press, Samaru-Zaria.
- LADP, 1978. Farm census report. EVL/T/L-1. Lafia Agricultural Development Project. Evaluation, Planning and Monitoring Department, Lafia, Plateau State, Nigeria.
- LADP, 1981. Enhanced LANDSAT imagery. Held by the Lafia Agricultural Development Project. Evaluation, Planning and Monitoring Department, Lafia, Plateau State, Nigeria.
- LAIRD, M., 1977. Tsetse: the Future for Biological Methods in Integrated Control. IDRC 077e. International Development Research Centre, Ottawa.
- LAVEISSIERE, C. and D. COURET, 1979. Le piege beconique impregne d'insecticide pour la lutte contre Glossine riveraines. In sixteenth meeting of the International Scientific Committee for Trypanosomiasis Research, Yaounde, pp 493-506.

- LINCOLN, F. C., 1930. Calculating waterfowl abundance on the basis of banding returns. U. S. Dept. Agric. Circ., 118 1-4.
- LINEAR, M., 1981. Zapping Africa's flies. Vole, March 1981.
- LINEAR, M., 1982. Gift of poison - the unacceptable face of development aid. *Ambio* 11 2-8.
- LOSOS and CHOUINARD, 1979. Pathogenicity of Trypanosomes. Proceedings of a workshop held in Nairobi, 20-23 November, 1978. IDRC 132e. International Development Research Centre, Ottawa.
- LRDC, 1979a. The Benue Valley. Volume 4 of: Land Resources of Central Nigeria. Agricultural Development Possibilities. Land Resources Study 29. Land Resources Development Centre, Ministry of Overseas Development, London.
- LRDC, 1979b. Standard land use analysis computer programme, modified by Read, Land Resources Development Centre, Ministry of Overseas Development, London.
- LRDC, 1981. An Atlas of Resource Maps. Volume 7 of: Land Resources of Central Nigeria. Agricultural Development Possibilities. Land Resources Study 29. Land Resources Development Centre, Ministry of Overseas Development, London.
- LUMSDEN, W. H. R., 1965. Biological aspects of trypanosomiasis research. *Advanc. Parasit.* 3 1-57.
- LUMSDEN, W. H. R., 1970. Biological aspects of trypanosomiasis research, 1965; a retrospect 1969. *Advanc. Parasit.* 8 227-249.
- MACFIE, J. W. S., 1913. The distribution of Glossina in the Ilorin province of Nigeria. *Bull. ent. Res.*, 4 1-28.
- MACLENNAN, K. J. R., 1955. Annual Report of the Veterinary Tsetse and Trypanosomiasis Unit for 1954-55.
- MACLENNAN, K. J. R., 1958. The distribution and significance of Glossina morsitans submorsitans in Northern Nigeria. Seventh meeting of the International Scientific Committee for Trypanosomiasis Research, Brussels, pp 357-365.
- MACLENNAN, K. J. R., 1964. Report on results from insecticidal control projects for the eradication of Glossina in the Sudan vegetation zone in Northern Nigeria. Tenth meeting of the International Scientific Committee for Trypanosomiasis Research, Kampala, pp 125-132.
- MACLENNAN, K. J. R., 1966. The extermination of Glossina in Northern Nigeria. WHO/FAO Seminar of Trypanosomiasis, Nairobi.
- MACLENNAN, K. J. R., 1967. Recent advances in techniques for tsetse control with special reference to Northern Nigeria. *Bull. Wld. Hlth. Org.*, 37 615-628.

- MACLENNAN, K. J. R., 1968. Fifty years of entomological research in relation to Glossina extermination: current progress and future trends in Northern Nigeria. Proc. ent. Soc. Nig. (1968) 83-87.
- MACLENNAN, K. J. R., 1970. The epizootiology of trypanosomiasis in livestock in West Africa. pp 751-765 in: The African Trypanosomiasis. Edited by H. W. Mulligan. George Allen and Unwin, London.
- MACLENNAN, K. J. R., 1974. The epizootiology of tsetse transmitted trypanosomiasis in relation to livestock development and control measures. pp 259-267 in: Les moyens de lutte contre les trypanosomes et les vecteurs: Actes du Colloque IEMVT, Paris.
- MACLENNAN, K. J. R., 1980. Tsetse-transmitted trypanosomiasis in relation to the rural economy in Africa. Part 1. Tsetse infestation. World Animal Review, 36 2-17.
- MACLENNAN, K. J. R., 1981. Tsetse-transmitted trypanosomiasis in relation to the rural economy in Africa. Part 2. Techniques in use for the control or eradication of tsetse infestation. World Animal Review, 37 9-19.
- MACLENNAN, K. J. R. and P. J. AITCHISON, 1963. The simultaneous control of three species of Glossina by the selective application of insecticide. Bull. ent. Res., 54 199-212.
- MACLENNAN, K. J. R. and W. W. KIRKBY, 1959. The eradication of Glossina morsitans submorsitans Newstead and G. tachinoides Westwood in part of a river flood plain in Northern Nigeria by chemical means. Bull. ent. Res. 49 123-131.
- MACLENNAN, K. J. R. and B. K. NA'ISA, 1971. The current status and future prospects regarding tsetse extermination in Nigeria. Thirteenth meeting of the International Scientific Committee for Trypanosomiasis Research, Lagos, pp 303-309.
- MAHOOD, A. R., 1960. An experiment on the control of Glossina palpalis (R.-D.) in southern Zaria Province, Northern Nigeria by chemical means. Eighth meeting of the International Scientific Committee for Trypanosomiasis Research, Jos, pp 269-276.
- MAHOOD, A. R., 1962. A note on the ecology of Glossina morsitans submorsitans Newstead in the Guinea savannah zone of Northern Nigeria. Ninth meeting of the International Scientific Committee for Trypanosomiasis Research, Conakry, pp 181-185.
- MARRIOTT, F. H. C., 1974. The Interpretation of Multiple Observations. Academic Press, London.
- MCEVEDY, C. and R. JONES, 1978. Atlas of World Population History. Penguin, London.

- MILLER, L. D. and D. L. WILLIAMS, 1979. Forest exploitation in the central Nigerian forest reserves. pp 9-13 in: Monitoring Forest Canopy Alteration Around the World with Digital Analysis of LANDSAT Imagery. Edited by D. L. Williams and L. D. Miller. National Aeronautics and Space Administration, Washington.
- MILLIGAN, K., D. M. BOURN and R. CHACHU, 1979. Dry and wet season patterns of cattle and land use in four regions of the Nigerian sub-humid zone. Report to International Livestock Centre for Africa, Sub-humid Programme, Kaduna.
- MORAN, P. A. P., 1951. Mathematical theory of animal trapping. *Biometrika*, 38 307-11.
- MOSIER, B., 1912. Notes on the haunts and habits of G. tachinoides near Geidam. *Bull. ent. Res.* 3 195-202.
- MULLIGAN, H. W. 1970. Editor: The African Trypanosomiases. George Allen and Unwin, London.
- NA'ISA, B.K., 1976. Comments on: Ecological effects of control of African trypanosomiasis, by W.E. Ormerod (1976). Cyclostyled.
- NASH, T. A. M., 1948. Tsetse flies of British West Africa. HMSO, London.
- NASH, T. A. M. and W. A. PAGE, 1953. The ecology of Glossina palpalis in northern Nigeria. *Trans. R. ent. Soc. Lond.*, 104 71-169.
- NIGERIAN VETERINARY SERVICES, 1925. Colony and Protectorate of Nigeria. Annual Report of the Veterinary Department for 1924/25.
- NIGERIAN VETERINARY SERVICES, 1928. Colony and Protectorate of Nigeria. Annual Report of the Veterinary Department for 1927/28.
- NORTON-GRIFFITHS, M. 1978. Counting Animals. East African Wildlife Leadership Foundation, Nairobi.
- NORD, M., 1982. An Atlas of Resource Maps: The Nigerian Sub-Humid Zone. International Livestock Centre for Africa, Sub-Humid Programme, Kaduna.
- O'CONNOR, A. M., 1978. The Geography of Tropical African Development. Pergamon Press, Oxford.
- OKONGO, C., 1968. A preliminary medium estimate of the 1962 mid-year population of Nigeria. pp 78-96 in: The Population of Tropical Africa. Edited by J. C. Caldwell and C. Okongo. Longmans, London.
- OLAYIDE, S. O., 1976. Economic Survey of Nigeria: 1969-1975. Aromolaran Publishing Co. Ibadan.
- ONAH, J., 1982. Tsetse Infection Rates in Pandam Wildlife Park. M. Sc. Thesis. University of Jos, Plateau State, Nigeria.

- ONYIAH, J. A., 1978. Fluctuations in numbers and the eventual collapse of a Glossina palpalis (R.-D.) population in Anara forest reserve, Nigeria. Acta Trop., 35 253-261.
- ORMEROD, W. E., 1976. The ecological effect of control of African trypanosomiasis. Science, 191 815-821.
- ORMEROD, W. E., 1979. Environmental and social consequences of tsetse eradication. Pastoral Network Paper 8b. Overseas Development Institute, London.
- ORMSBY-GORE, W., 1925. Chairman: Report of the East African Commission. Cmd. 2387. HMSO, London.
- OXBY, C., 1982. Progress in the settlement of nomadic herders in the sub-humid zone. Food and Agriculture Organisation of the United Nations, Rome.
- PAGE, W. A., 1959a. The ecology of Glossina longipalpis Wied. in southern Nigeria. Bull. ent. Res. 50 633-646.
- PAGE, W. A., 1959b. The ecology of Glossina palpalis (R.-D.) in southern Nigeria. Bull. ent. Res. 50 617-631.
- PETERSEN, C. G. J., 1896. The yearly immigration of young plaice into Limfjord from the German sea. Rept. Danish Biol. Stn., 6 1-48.
- POLLARD, J., 1912. Notes on the tsetse flies of Muri Province Northern Nigeria. Bull. ent. Res., 3 219-221.
- POLLOCK, J. N., 1982. Editor: Training Manual for Tsetse Control Personnel. Food and Agriculture Organisation of the United Nations, Rome.
- POPHAM, E. J., 1972. Geographical factors controlling the distribution of tsetse flies in Northern Nigeria. Bul. ent. Soc. Nig., 3 147-150.
- POTTS, W. H., 1953/54. The distribution of tsetse species in Africa. Map sheets 1, 2 and 3. Directorate of Colonial Surveys, London.
- PULLAN, R. A., 1962. The concept of the middle belt of Nigeria - an attempt at a climatic definition. J. geogr. Assoc. Nigeria, 5 39-52.
- PURSEGLOVE, J. W., 1968. Tropical Crops: Dicotyledons. Longmans, London.
- PURSEGLOVE, J. W., 1972. Tropical Crops: Monocotyledons. Longmans, London.
- PUTT, S. N. H., 1979. Comments on: Environmental and social consequences of tsetse eradication, by W. E. Ormerod (1979). Pastoral Network Paper 9f. Overseas Development Institute, London.

- PUTT, S. N. H., A. P. M. SHAW, R. W. MATHEWMAN, D. M. BOURN, M. UNDERWOOD, A. D. JAMES, M. J. HALLAM and P. R. ELLIS, 1980. The Social and Economic Implications of Trypanosomiasis Control: A Study of its Impact on Livestock Production and Rural Development in Northern Nigeria. Study No. 25. Veterinary Epidemiology and Economics Research Unit, Reading University.
- RIORDAN, K., 1976. Rate of linear advance of Glossina morsitans submorsitans Newstead (Diptera: Glossinidae) on a trade cattle route in South-Western Nigeria. Bull. ent. Res., 66 365-372.
- ROGERS, D. J., 1977. Study of a natural population of Glossina fuscipes fuscipes Newstead and a modal of fly movement. J. Anim. Ecol. 46 309-330.
- ROGERS, D. J. and S. E. RANDOLPH, 1982. The ecology, distribution and spread of Glossina palpalis. Report of second year's work to WHO/OMS Special Programme, Levehulme Trust and Overseas Development Administration.
- ROSEVEAR, D. R., 1953. Checklist and Atlas of Nigerian Mammals. Government Printer, Lagos.
- RUTHENBERG, H., 1976. Farming Systems in the Tropics. Clarendon Press, Oxford.
- RYAN, L. and D. H. MOLYNEUX, 1980. Construction details of the Challier/Laveissiere biconical trap. pp 339-353 in: Isotope and Radiation Research on Animal Diseases and their Vectors. Proceedings of a symposium held in Vienna, 7-11 May, 1979. International Atomic Energy Agency, Vienna.
- RYAN, L., D. H. MOLYNEUX, N. HARRISON and M. HILLER, 1981. An automatic tsetse (Diptera: Glossinidae) trap. Tropical Pest Management, 27 115-115.
- SAUNDERS, D. S. and R. J. PHELPS, 1970. Reproduction of Glossina : Breeding sites. pp 327-347 in: The African Trypanosomiasis. Edited by H. W. Mulligan. George Allen and Unwin, London.
- SEBER, G. A. F., 1973. The Estimation of Animal Abundance and Related Parameters. Griffin, London.
- SIMPSON, J. J., 1912a. Entomological research in West Africa: II Northern Nigeria. Bull. ent. Res., 2 301-356.
- SIMPSON, J. J., 1912b. Entomological research in West Africa: III Southern Nigeria. Bull. ent. Res., 3 137-193.
- SOUTHWOOD, T. R. E., 1978. Ecological Methods, with Particular Reference to the Study of Insect Populations. Chapman Hall, London.

- SPIELBERGER, U. and U. ABDURRAHIM, 1971. Pilot trials of discriminative aerial application of persistent Dieldrin deposits to eradicate Glossina morsitans submorsitans in the Anchau and Ikara forest reserves, Nigeria. Thirteenth meeting of the International Scientific Committee for Trypanosomiasis Research, Lagos, pp 271-281.
- SPIELBERGER, U., B. K. NA'ISA and U. ABDURRAHIM, 1977. Tsetse (Diptera: Glossinidae) eradication by aerial (helicopter) spraying of persistent insecticides in Nigeria. Bull. ent. Res., 67 589-598.
- STEPHEN, L. E., 1970. Clinical manifestations of the trypanosomiasis in livestock and other domestic animals. pp 774-794 in: The African Trypanosomiasis. Edited by H. W. Mulligan. George Allen and Unwin, London.
- SPSS, 1982. Statistical Package for the Social Sciences. (Hewlett Packard 3000 version). International Livestock Centre for Africa, Addis Ababa.
- SYMES, C. B., A. B. HADAWAY, F. BARLOW and W. GALLEY, 1948. Field experiments with DDT and Benzene Hexachloride against tsetse (Glossina palpalis). Bull. ent. Res. 38 Res., 591-612.
- TAKKEN, W., F. L. G. DE BRUIJCKERE and J. H. KOEMAN, 1976. Environmental impact studies concerning the fixed-wing aircraft Endosulfan applications in the southern Guinea savanna zone in Nigeria. Report to the Dept. Toxicol. Agr. Univ. Wageningen, the Netherlands.
- TIFFIN, M., 1976. The Enterprising Peasant. Economic Development in Gombe Emirate, North-Eastern Nigeria, 1900-1968. Overseas Research Publication No. 21. Ministry of Overseas Development, London.
- TTD, 1954 to 1978. Annual reports of the Tsetse and Trypanosomiasis Division (formerly the Veterinary Tsetse and Typanosomiasis Unit) of the Nigerian Federal Livestock Department (formerly Department of Veterinary Services), Kaduna.
- UDO, R. K., 1968. Population and politics in Nigeria. pp 97-105 in: The Population of Tropical Africa. Edited by J. C. Caldwell and C. Okongo. Longmans, London.
- UDO, R. K., 1975. Migrant Tenant Farmers of Nigeria. African Universities Press, Lagos.
- VANDERPLANK, F. L., 1947. Experiments with DDT on various species of tsetse flies in the field and laboratory. Trans. R. Soc. trop. Med. Hyg. 40 603-620.
- VAN RAAJ, J. G. T., 1975. Rural Planning in a Savannah Region. Rotterdam University Press.
- VOS, A. DE, 1978. Must Africa suffer the environmental consequences of tsetse fly control? Unasyiva.

- WEITZ, B. G. F., 1963. The feeding habits of Glossina. Bull. Wld. Hlth. Org. 28 711-729.
- WEITZ, B. G. F., 1970. The hosts of Glossina. pp 317-326 in: The African Trypanosomiasis. Edited by H. W. Mulligan. George Allen and Unwin, London.
- WHITE, F., 1983. Vegetation of Africa: Descriptive Memoir to Accompany the UNESCO/AETAT/UNSO Vegetation Map of Africa. UNESCO, Paris.
- WHO, 1963. Trypanosomiasis. Bull. Wld. Hlth. Org. 28 537-836.
- WILLIAMSON, G. and W. J. A. PAYNE, 1978. An Introduction to Animal Husbandry in the Tropics. Longman, London.
- WILSON, S. G., 1958. Recent advances of Glossina morsitans submorsitans in Northern Nigeria. Seventh meeting of the International Scientific Committee for Trypanosomiasis Research, Brussels, pp 367-389.
- WORLD BANK, 1977. World Bank Atlas: Population, Per Capita Product and Growth Rates. World Bank. Washington.
- WORLD BANK, 1979. World Development Report, 1979. Oxford University Press.
- YUSUFU, T. M., 1968. The politics and economics of Nigeria's census. pp 106-116 in: The Population of Tropical Africa. Edited by J. C. Caldwell and C. Okongo. Longmans, London.
- ZIPPIN, C., 1956. An evaluation of the removal method of estimating animal populations. Biometrics, 12 163-89.
- ZIPPIN, C., 1958. The removal method of population estimation. J. Wildl. Mgmt., 22 82-90.

APPENDIX 1 BIOLOGICAL CONTROL OF TSETSE IN NIGERIA:  
Results of the pilot release programme.

This appendix describes the establishment of BICOT's pilot sterile male release programme in the region of Nigeria considered in chapters 6 and 7, and presents an analysis of the preliminary results. It covers the period January to May 1982, and is based on a report submitted to the Federal Department of Pest Control Services and the joint division of the International Atomic Energy Agency and the Food and Agriculture Organisation of the United Nations. The programme was subsequently extended and is still in progress.

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## 1 OBJECTIVES

The primary objectives of the pilot release programme were to:

develop and establish appropriate sterile male transport, release and quality control procedures;

initiate a suitable sampling scheme for monitoring wild tsetse populations;

assess the survival and dispersal of sterile males after release;

demonstrate the impact of sterile males released into a wild population of G. palpalis;

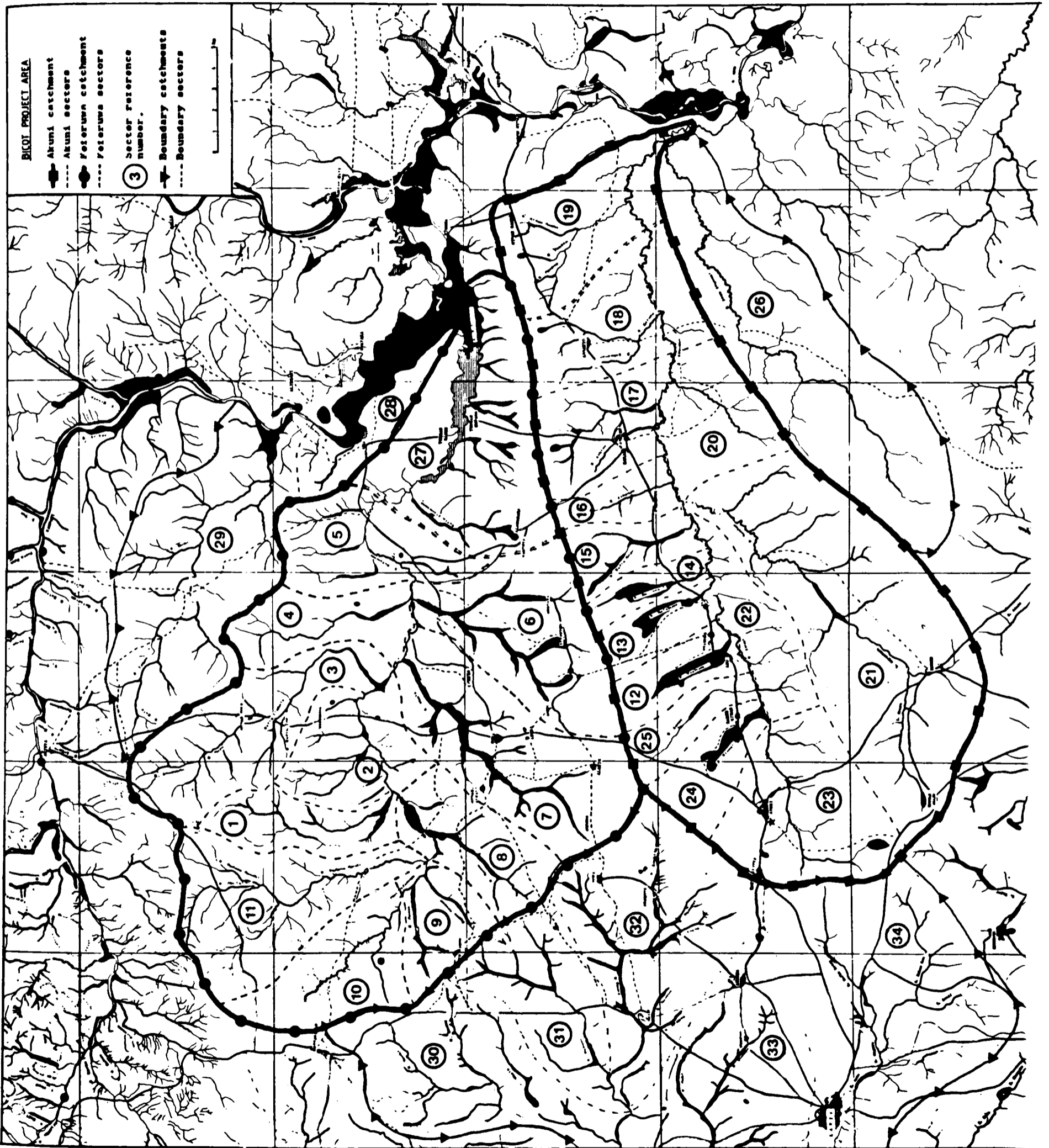
### 1.1 Choice of Pilot Release Zone.

Previous project reports have described the criteria for initial selection of the BICOT project area (Bourn and Oladunmade, 1980), and the findings of the preliminary field work (Oladunmade and Bourn, 1981). Following environmental analysis, extensive tsetse distribution and population studies within the Feferuwa-Akuni project area (figure A1.1), it was decided that the headwaters of the Akuni catchment provided the most suitable conditions for conducting a pilot release programme of sterile male G. palpalis.

The Akuni catchment as a whole had a lower proportion of riverine forest tsetse habitat than either the Feferuwa or the boundary catchments; and also a higher proportion of narrow forest, as opposed to wide forest. Narrow forests generally support much lower numbers of G. palpalis than wide forests. Overall populations of both G. palpalis and G. tachinoides were considerably lower in the Akuni catchment - and where wide forests occurred G. palpalis was found at lower concentrations than elsewhere. (See table A1.1 for quantitative values.)

Proximity to the BICOT Adogi base camp and good all weather accessibility throughout the pilot release zone were also important considerations in the choice of area.

FIGURE A1.1 : BICOT PROJECT AREA





The zone chosen for the pilot release programme comprised of eight sub-catchment sectors: 12, 13, 14, 15, 22, 23, 24 and 25 (See maps: figure A1.1 and figure A1.2 ), and had a total land area of 170 km<sup>2</sup>. There were 91 km of riverine forest, covering some 1022 ha, of which 777 ha were wide forest and 235 ha narrow forest.

One of the principal features of interest in the zone was the presence of four superficially similar and adjacent forest islands, each surrounded by extensive areas of cultivation: Kireyi (sector 24); Tsakuwa (12) ; Maikuya (13) and Maisamari (14). Perennial spring fed streams and ground seepage rising from the Lafia Sandstone formation sustain these forests patches, and are the primary sources of the Akuni. Technically these forests have been protected reserves for many years, but in reality there has been a considerable degree of encroachment by cultivation and substantial deforestation has taken place as a result of the extraction of valuable timber, canoe construction, firewood collection and palm wine production.

These processes have undoubtedly been operating for some considerable period of time, but appear to have accelerated since the last aerial photographic survey was carried out in 1974, when the new tarmac road from Lafia to Shendam was under construction. This road runs just north of, and parallel to, the Akuni river and cuts across the southern portions of the four forest patches. Formerly continuous forest cover extended to the Akuni, but this has now been removed and replaced by grassland, dry season irrigated fields, fish ponds and a few dense thickets.

Riverine forest cover is thus discontinuous and, at least, during the height of the dry season, it seemed likely that the G.palpalis populations within these forest patches were largely isolated from each other. This provided the opportunity of designing a sterile male release programme which incorporated a variety of different treatments, and assessing their suitability.

1.2 Plan of Operation.

Within the Feferuwa-Akuni project area, which lies close to the northern limits of G.palpalis in Nigeria, the fly's distribution is largely confined to riverine forest habitats. During the dry season narrow fringing forest, like that on the Akuni river, with poor insulation capacity can be regarded as marginal habitat; while the more extensive wide forest islands with greater insulation afford more favourable habitat.

Essentially the plan of operation consisted of five phases:

Pre-release tsetse population monitoring in all sectors of the pilot release zone, using biconical traps.

Varying degrees of tsetse population suppression in the forest islands by periods of long term trapping. Followed by

Sequential release of marked sterile male G.palpalis within the forest islands at two week intervals; and

Concurrent continuous trapping in the marginal surrounding habitat; with

Regular trap catch collections to monitor tsetse populations throughout.

The initial plan period ran for four months - from mid-January to mid-May 1982. Pre-release monitoring took place in January and February with two consecutive days trapping each month. On the basis of the measures of relative abundance obtained it was decided to treat the G.palpalis populations in the four forest islands as follows:

TABLE A1.1 : PRE-RELEASE RELATIVE ABUNDANCE AND FOREST TREATMENT

FOREST	RELATIVE ABUNDANCE <u>G.palpalis</u> /trap/day		TREATMENT
	January	February	
Kireyi	0.9	1.5	Sterile Male Release (S.M.R.) only
Tsakuwa	3.3	3.6	"Short" suppression prior to S.M.R.
Maikuya	1.0	2.4	No suppression; No S.M.R.
Maisamari	4.1	4.1	"Long" suppression prior to S.M.R.

The diary of field operations during the pilot release programme until the middle of May 1982 is given in table A1.2. It shows the sampling scheme used to monitor tsetse populations; the population suppression periods; the timing of the staggered sterile male releases in the forest islands; and the continuous trapping in the surrounding sectors.

TABLE A1.2 : PILOT RELEASE PROGRAMME - TRAPPING AND RELEASE FIELD DIARY

SECTOR NUMBER	24	12	13	14	15,22,23,25
SECTOR NAME	KIREYI	TSAKUWA	MAIKUYA	MAISAMARI	RAFIN GOGO, AKUNI & AKUNI
TREATMENT	SMR only	"Short" population suppression prior to SMR	Monthly sampling only	"long" population suppression prior to SMR	Continuous trapping
DATE					
Th Jan 14	◇	◇	◇		
F 15	◇	◇	◇		◇
S 16					◇
M 25				◇	
T 26				◇	
F Feb 19	◇	◇			
S 20	◇	◇			
S 21					
M 22			◇	◇	
T 23			◇	◇	
F March 12		◇		◇	
S 13		◇		◇	
S 14		◇		◇	
M 15		◇		◇	
T 16	◇	◇		◇	◇
W 17	◇	◇	◇	◇	◇
TH 18	◆	◇		◇	◇
F 19		◇		◇	◇
S 20		◇		◇	◇
S 21		◇		◇	◇
M 22		◇		◇	◇
T 23		◇		◇	◇
W 24		◇		◇	◇
TH 25		◆		◇	◇
F 26		◇		◇	◇
S 27		◇		◇	◇
S 28		◇		◇	◇
M 29		◇		◇	◇
T 30	◇	◇		◇	◇
W 31	◇	◇		◇	◇
Th April 1	◆			◇	◇
F 2				◇	◇
S 3				◇	◇
S 4				◇	◇
M 5				◇	◇
T 6		◇		◇	◇
W 7		◇		◇	◇
TH 8		◆		◇	◇
F 9		◇		◇	◇
S 10		◇		◇	◇
S 11		◇		◇	◇
M 12		◇		◇	◇
T 13		◇		◇	◇
W 14	◇	◇	◇	◇	◇
TH 15	◇	◇		◇	◇
F 16	◆			◆	◇
S 17				◇	◇
S 18				◇	◇
M 19		◇		◇	◇
T 20		◇		◇	◇
W 21		◆			◇
TH 22		◆			◇
F 23		◇			◇
S 24		◇			◇
S 25		◇			◇
M 26		◇		◇	◇
T 27	◇	◇		◇	◇
W 28	◇	◇		◆	◇
TH 29	◆				◇
F 30					◇
S May 1					◇
S 2					◇
M 3		◇		◇	◇
T 4		◇		◇	◇
W 5		◇		◇	◇
TH 6		◆			◇
F 7		◇			◇
S 8		◇			◇
S 9		◇			◇
M 10		◇	◇	◇	◇
T 11	◇	◇		◇	◇
W 12	◇	◇		◇	◇
TH 13	◆			◆	◇

◇ Trapping, daily collection. ◆ Trapping, no collection. ◆ Sterile Male Release.  
 ◆ Intermittent sampling

2 PRE-RELEASE SURVEY

Tsetse population distribution and relative abundance were determined in all sectors of the pilot release zone during January, February and March, using biconical traps sampling for two consecutive days each month. The location of the 114 trap sites used is shown on the pilot release zone map (figure A1.2). This map was derived from the most recent aerial photography available (1974) and accurately represents the extent of narrow and wide forest habitats in existence then. However during the course of ground work it became clear that in the intervening eight years since the photography was taken a considerable degree of deforestation had taken place. In particular the wide forest at the south-western headwaters of the Akuni; the wide forest on the Kireyi south of the main road and at the confluence with the Akuni; much of the northern part of the Tsakuwa forest and most of the Rafin Gogo forest; no longer existed.

Trap sites were selected on the basis of the most suitable positions available within a given area, as described by Dengwat, 1981. All sites were marked for future identification. In the narrow fringing forest along the Akuni the majority of traps were sited at crossing/watering points with good up and down stream visibility. The distance apart varied between 500 - 1000 meters. At the eastern end of the Akuni traps were sited closer together, 250 meters apart, in an attempt to create a partial barrier to dispersal from down stream. In the four forest islands traps were positioned approximately 250 meters apart within the core area along the central stream; wherever possible crossing/watering points with good visibility were utilized.

The summarised results of the March pre-release survey are shown in figure A1.3. The radius of the central circles indicates the relative abundance of tsetse caught per trap per day in each of the sectors; black represents the proportion of G. palpalis; white the proportion of G. tachinoides. The histograms show the composition of the catch for each species; G. palpalis to the right, G. tachinoides to the left; hatched areas represent teneral, unhatched non-tenerals.

> 5.00 Glossino trap<sup>-1</sup> day<sup>-1</sup> "  
2.00-4.99 " " "  
1.00-1.99 " " "  
0.50-0.99 " " "  
< 0.50 " " "

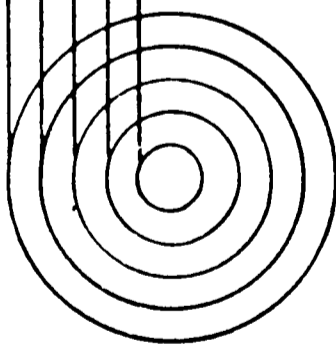
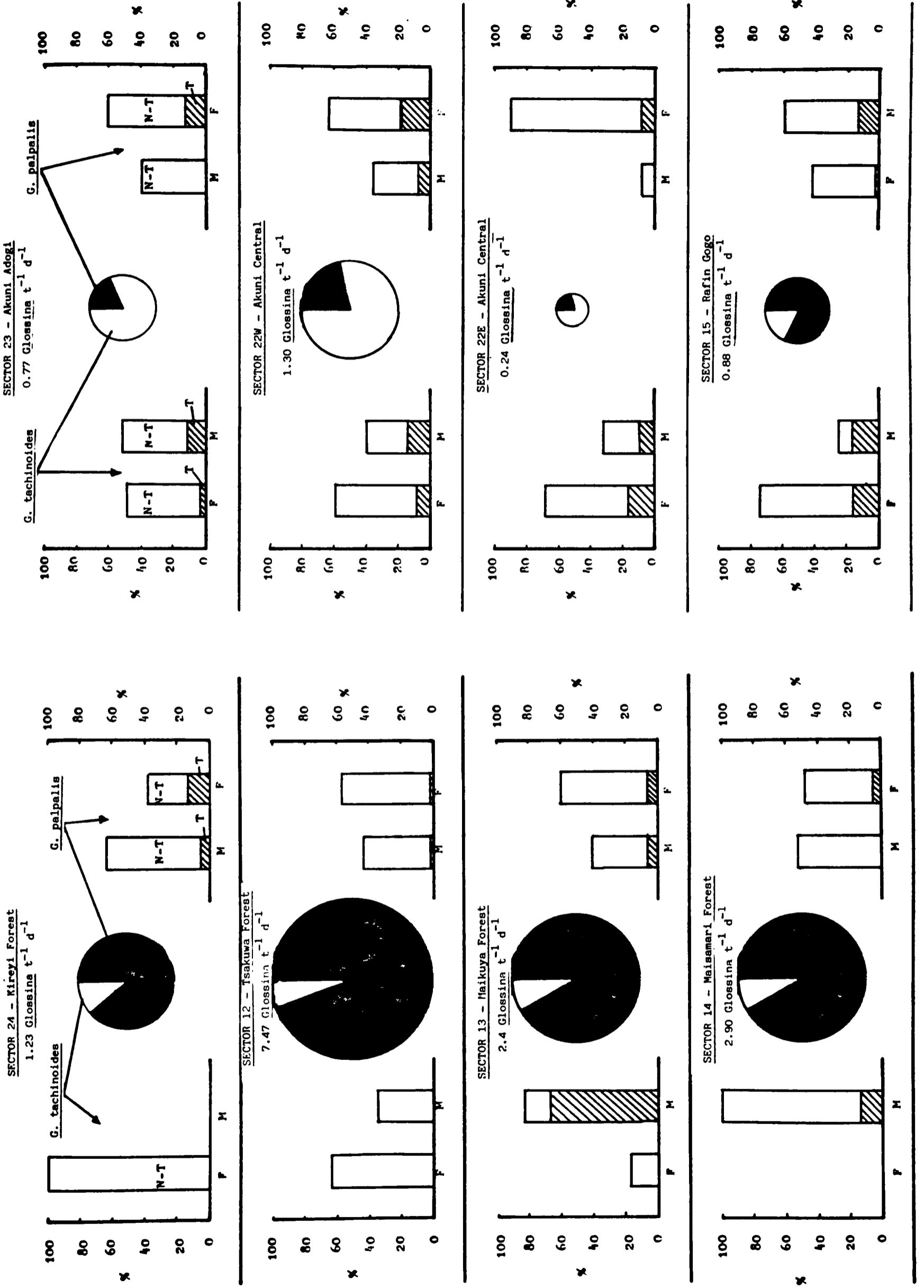


FIGURE A1.3 : PRE-RELEASE TSETSE DISTRIBUTION AND RELATIVE ABUNDANCE.



The species composition and relative abundance of tsetse in the various sectors is clearly not uniform. In Kireyi, Tsakuwa, Maikuya and Maisamari forest islands, where relative abundance was highest, and in Rafin Gogo more than 75% of the catch was G.palpalis; while in the various sectors of the Akuni more than 75% of the catch was G.tachinoides.

These results confirm the findings of earlier tsetse surveys, that the four forest islands in sectors 12,13,14 and 24 constituted the most important G. palpalis habitats within the pilot release zone. These forests were the focus of attention during the release programme.

### 3 SELECTION OF RELEASE POINTS.

The choice of sterile male release points was influenced by two factors:

The desirability of sterile males dispersing throughout the available forest habitat and mixing thoroughly with the wild population; and

the importance of sterile males finding virgin females.

Pre-release population suppression by continuous trapping in Tsakuwa and Maisamari provided information on the distribution of G.palpalis. Traps were located at approximately 250 m intervals from each other along the stream in the central core area of the two forests, and collections made daily. The total catch per trap over the first twelve days gave an indication of distribution within the forest, and the numbers of teneral flies where emergence was greatest. (see figure A1.4)

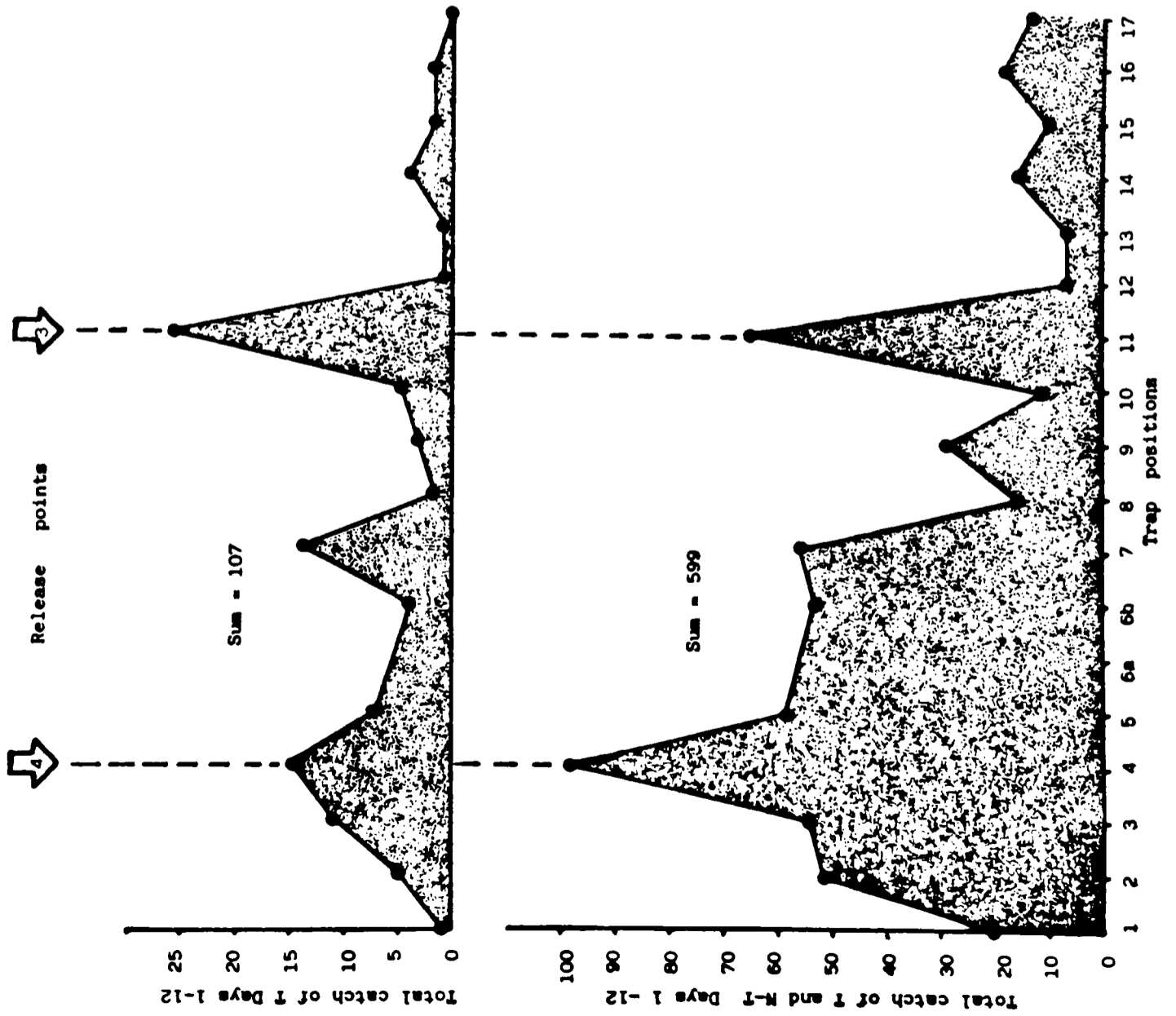
The release points chosen were trap sites 4 and 11 in Tsakuwa; and 1 and 10 in Maisamari.

No prior suppression took place in Kireyi and very few flies were taken in the pre-release sample. The release points chosen were a third of the way down and a third of the way up the forest, trap positions 4 and 8.

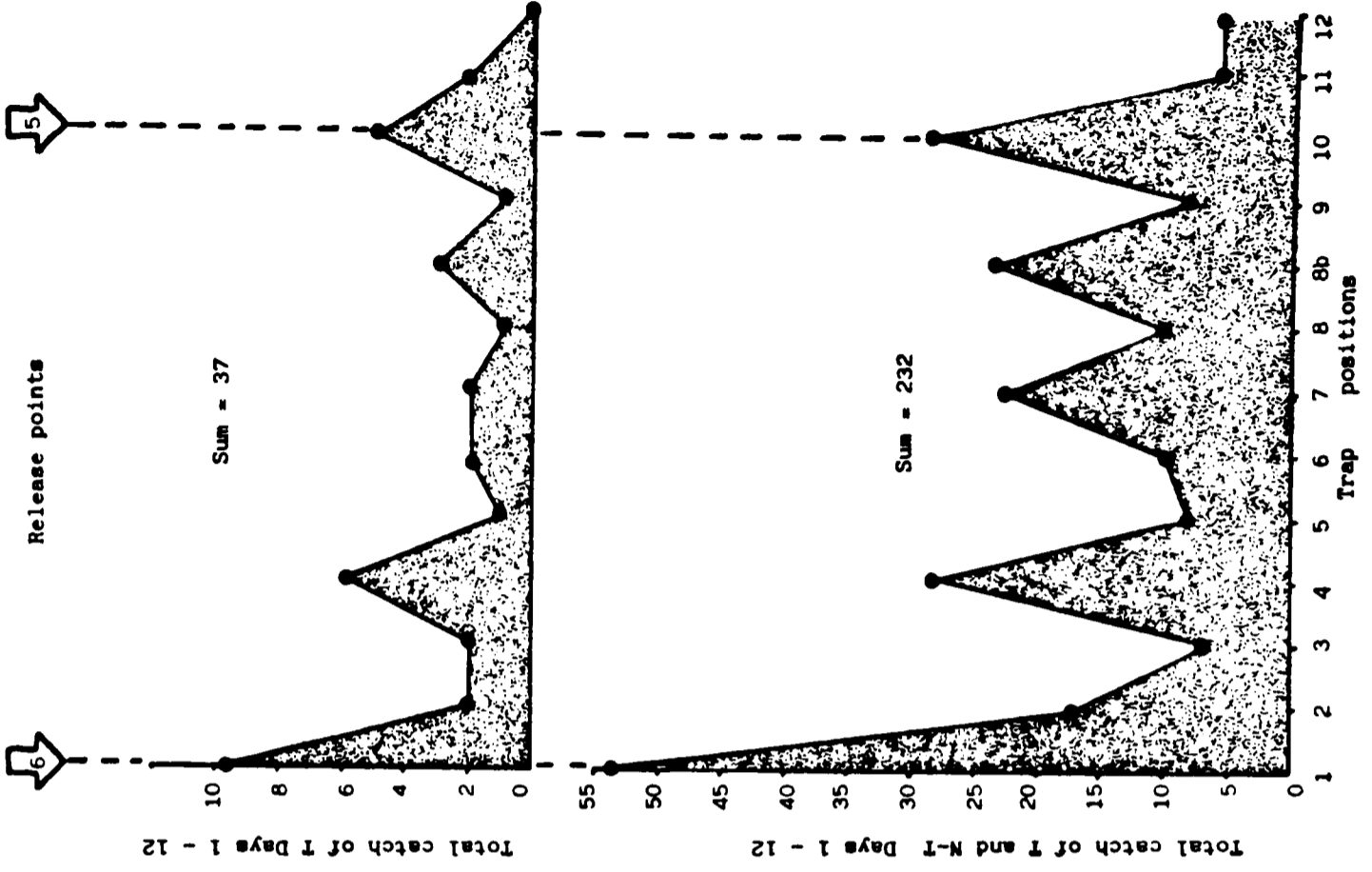
The locations of the six release points are shown on the pilot release zone map (figure A1.2).

FIGURE A1.4 : G. PALPALIS CATCH DISTRIBUTION

Sector 12 - Tsakuva



Sector 14 - Maisamari



4 STERILE MALE TRANSPORT AND RELEASE.

During the course of the BICOT pilot release programme some 11,047 sterile males were released at six release points in three forest patches.

The flies were usually 2-3 days old at release, which normally took place on Thursday mornings, having emerged and been marked in the Vom insectaries on Monday and Tuesday, and given a final blood meal on Wednesday morning before being transported the 220 km by road to Adogi field camp late on Wednesday afternoon.

The sterile males were carried in 10 l plastic containers with netting sides, covered with damp towels and packed in insulated wooden boxes containing two chilled "cooler packs". Each container usually contained about 250 sterile males, but exceptionally the number was increased to about 500. Regular container temperature checks were made during transportation. Journey time from Vom to Adogi was approximately three hours and internal container temperature ranged from 24 - 28 ° C. On arrival dead flies were counted and containers stored overnight on ant-proof supports in the laboratory.

The following morning any flies required for quality control studies were removed, and the remaining flies taken to their respective release point. At release air temperature below 25° C, the duration of release was found to be excessive, so on cooler days release was delayed until ambient temperatures had risen above this level. Releases took place between 09.00 and 12.00, the duration of each release usually being less than 5 minutes; ambient temperatures ranged from 25 - 31°C.

As well as a few dead flies remaining in the release cages after each release there were also some live flies which were unable to fly. The number of dead and non-flying flies were counted and recorded separately.

Table A1.3 summarises the transportation and pre-release mortalities as well as the number of non-fliers as percentages of the number dispatched. Mortality during transportation was low (0.3%); at the time of release total mortality was 1.6%. The proportion of non-fliers was 3.2% (1.4% for in vivo; 4.2% for in vitro). 95% of flies sent from Vom were released.

Table A1.4 summarises the total numbers of sterile males released by forest, release point and colony of origin during the first nine weeks of releases.

Table A1.5 shows the marking schedule used and the number of flies released each week at the six release points in the three forests.

TABLE A1.3 : STERILE MALE TRANSPORTATION AND PRE-RELEASE LOSSES

COLONY OF ORIGIN	% MORTALITY		% ALIVE NON-FLIERS AT RELEASE	% TRANSPORTED STERILE MALES RELEASE
	DURING TRANSPORT	TOTAL PRIOR TO RELEASE		
IN VIVO	0.3	1.9	1.4	96.7
IN VITRO	0.3	1.3	4.2	94.5
OVERALL	0.3	1.6	3.2	95.2

TABLE A1.4 : TOTAL NUMBER OF STERILE MALES RELEASED BY FOREST AND RELEASE POINT; RELEASES # 1 - 9

FOREST	RELEASE POINT	COLONY OF ORIGIN		SUM
		IN VIVO	IN VITRO	
KIREYI	1	575	1413	1988
	2	1298	815	2113
	SUM	1873	2228	4101
TSAKUWA	3	1074	948	2022
	4	1857	650	2507
	SUM	2931	1598	4529
MAISAMARI	5	886	60	946
	6	641	830	1471
	SUM	1521	890	2417
SUM		6331	4716	11047

TABLE A1.6 : STERILE MALE MARKING QUALITY - INTENDED AND ACTUAL MARKING.

	Intended marking position.				Sum
	1	2	3	4	
1	76	0	0	0	76
2	1	34	0	1	36
3	0	5	46	0	51
4	1	0	0	27	28
No Mark	12	12	1	1	26
Sum	90	51	47	29	217

Total not marked = 26 12.0 %

Total incorrectly marked = 8 3.7 %

TABLE A1.5 : NUMBER, DATE AND LOCATION OF STERILE MALE RELEASES

RELEASE FOREST	RELEASE POINT	MARKING COLOUR *	KIREYI 24			TSAKUWA 12			MAISAMARI 13			SUM											
			1			2			3				4			5			6				
			In vivo	In vitro	In vitro	In vivo	In vitro	In vitro	In vivo	In vitro	In vitro		In vivo	In vitro	In vitro	In vivo	In vitro	In vitro	In vivo	In vitro	In vitro		
# 1 18 March		ORANGE (green)	235 p1	234 p1	232 p2	198 p2																899	
# 2 25 March		WHITE (yellow)					243 p1	237 p1	241 p2	174 p2													895
# 3 1 April		GREEN (red)		476 p1	224 p2	244 p2																	944
# 4 8 April		YELLOW (blue)					244 p1	239 p1	233 p2	206 p2													922
# 5 16 April		BLUE (green)	50:50 388 p1		50:50 370 p2												249 p4					425 p3	1432
# 6 22 April		ORANGE (green)					239 p1	243 p1	950 p2	38 p2													1470
# 7 29 April		WHITE (red)		301 p2	521 p1												493 p2					473 p1	1788
# 8 6 May		GREEN (blue)					348 p2	229 p2	433 p1	232 p1													1242
# 9 13 May		ORANGE (-)	146 p2	208 p2	136 p3	188 p3										144 p4	60 p4	216 p1	357 p1				1455
TOTALS			575	1413	1298	815	1074	948	1857	650	886	60	641	830	11047								

\* External paint colour in CAPITALS; internal fluorescent dust in ( ).

5 QUALITY CONTROL OF RELEASED STERILE MALES.

As well as various tests on the fertility and competitiveness of sterile males performed, as part of quality control procedures, in the laboratory, checks on marking and survival were also carried out in the field.

5.1 Marking.

Sterile male G.palpalis released during the pilot release programme were externally marked on the dorsal surface of the thorax with small dots of fast drying acrylic paint, so that they could be distinguished from wild males during subsequent tsetse population monitoring.

Releases took place on a weekly basis from six release points in three adjacent forest patches. A different colour was used each week and different marking positions were used for the various release sites. (FAO,1982) On the basis of the colour and position code of recaptured marked flies it was thus possible to determine when and where they had originally been released.

A small proportion of the marked sterile males died before release, or failed to take off at the time of release. These flies provided a sample for quality control studies of the reliability of marking procedures. After release the remaining flies in each cage, which should all have had identical markings were individually examined and their actual marking recorded. As relatively few flies were available from this source, the results from each release have been pooled and are summarised in table A1.6.

Of the 217 sterile males examined 26 (12%) were not marked at all; and the marking positions of eight flies (4%) were incorrect.

From this sample it would appear that about 16% of the sterile males released were either not marked or were incorrectly marked. Whether or not this figure reflects that for the the sterile males actually released of course depends on how representative the sample was. However in view of the relevance of the information on movement, survival and the ratio of sterile to wild males, that recapture analysis can provide, it seems clear that the quality and reliability of marking procedures must be improved.

## 5.2 Field Cage Survival.

Sub-samples of ten sterile male G.palpalis were removed from each release cage prior to release (after feeding in Vom, and transportation to Adogi) and placed in small cages. Immediately after release these cages of flies were suspended in what was considered to be the most suitable conditions available within the forest of release - ie in positions of deep shade, moderate temperature and high humidity, if possible near running water or over damp soil. An encircling blob of "ecotak" was smeared around each suspension string, in order to prevent ant invasion.

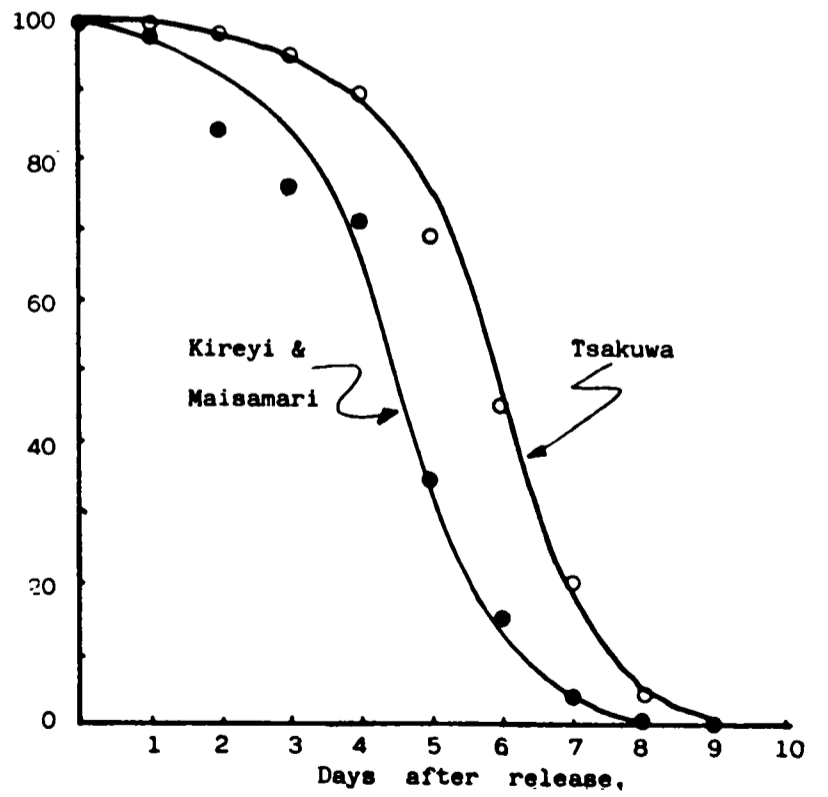
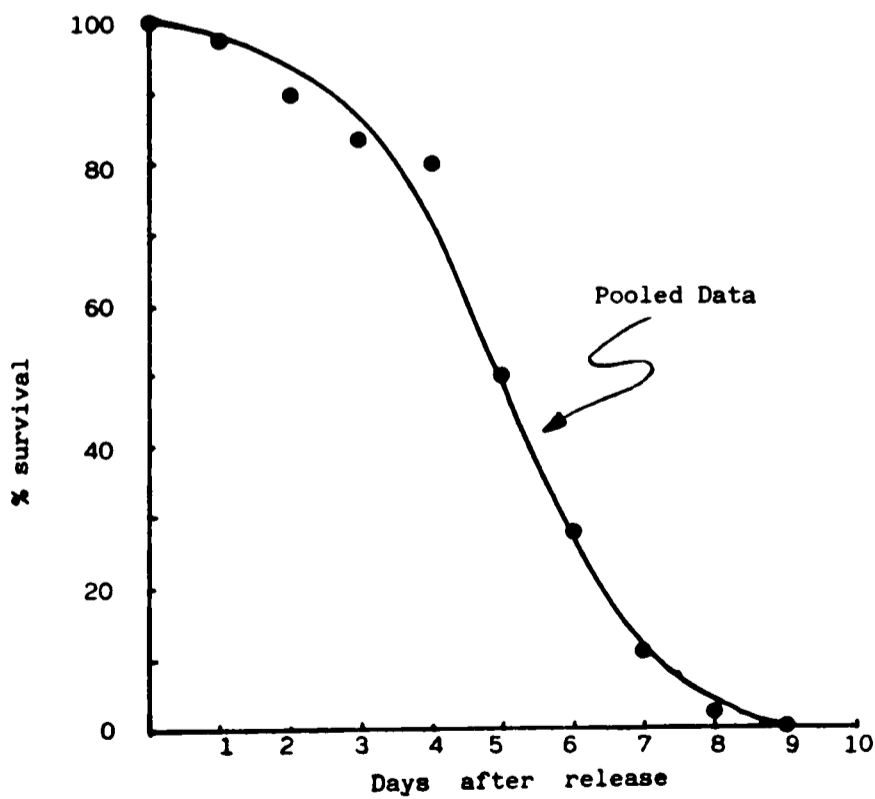
Subsequently each cage was visited daily and the number of surviving flies recorded until all flies had died. The flies used had been fed at Vom on Guinea pigs before transportation to Adogi and 24 hours before placement in the field. Thereafter they were not fed again. The results obtained do not represent the actual survival of released sterile males, which obviously may have had the chance of finding a host and a blood meal; they do however indicate the period of time available to pre-fed released flies in which to find a host.

The overall survival of the 360 caged sterile males is shown to the left of figure A1.5. Approximately 75% survived until day 4 after release (day 5 after feeding); 50 % survived until day five after release (day 6 after feeding); all were dead by day 9 after release (day 10 after feeding).

These caged survival observations took place during the height of the dry season (March and April), when general climatic conditions were most extreme. Although the forests in which they were carried out provided a considerable degree of insulation, microclimatic conditions within them were nevertheless also effected. Survival of caged sterile males within Tsakuwa, which subjectively appeared to afford the best G.palpalis habitat of the three release forests, was appreciable greater than either Kireyi or Maisamari - compare the pair of survival curves to the right of figure A1.5.

FIGURE A1.5 : STERILE MALE FIELD CAGE SURVIVAL

DAYS AFTER		POOLED DATA		KIREYI & MAISAMARI		TSAKUWA	
FEEDING	RELEASE	N	%	N	%	N	%
1	0	360/360	100	200/200	100	160/160	100
2	1	353/360	98	195/200	98	158/160	99
3	2	324/360	90	167/200	84	157/160	98
4	3	287/340	84	145/200	76	142/150	95
5	4	255/320	80	121/170	71	134/150	89
6	5	169/340	50	66/190	34	103/150	69
7	6	94/320	28	27/190	15	67/150	45
8	7	38/340	11	7/190	4	31/150	20
9	8	8/340	2	2/190	1	6/150	4
10	9	0/340	0	0/190	0	0/150	0



## 6 TSETSE POPULATION MONITORING

Tsetse populations in the four release forests were sampled using biconical traps set at fixed sites, with daily collections for two consecutive days. The location of trapping sites is shown on the pilot release zone map (figure A1.2) and the sampling schedule is given in the field diary (table A1.2). The density of traps was approximately the same in all forests - about 1 trap per hectare of forest or 1 trap per 250 m of forest length.

Flies were collected and trap cages changed each morning; the catch was examined at the Adogi field laboratory as soon as possible after collection. Records were kept of the number, sex, species, teneral or non-teneral status for each trap; wing fray, ovarian stage and uterine content were also determined, except when flies were too dry for dissection. The colour and position code of any marked sterile males were also recorded; and wherever possible recaptured sterile males were dissected for trypanosome infection.

Figure A1.9 shows the changes in relative abundance of G.palpalis observed in the four forest islands from January to May 1982. The solid lines and dots are for the total catch of both teneral and non-teneral males and females; the dashed lines and open circles are for the female catch alone.

Of particular interest is the persistent increase in relative abundance of G.palpalis throughout the period in Maikuya, where no long term trapping or sterile male releases took place. The seven-fold increase in four months is too high to be accounted for by natural population increase. Neither can the increase be explained by immigration - under the prevailing conditions of advancing dry season and the semi-isolation of the forest population, significant influx is most unlikely. The increase in relative abundance is best explained by a combination of other factors:

A concentration of G.palpalis within the forest central core, resulting from increasingly severe peripheral environmental conditions: temperature, aridity, defoliation and fire encroachment, all of which would have the effect of reducing the extent of suitable microhabitat;

and increased tsetse activity with increasing mean temperature which would increase their chances of being caught.

The impact of continuous trapping and sterile male release on G.palpalis populations in the other three adjacent forests must be interpreted in the context of this underlying trend of increasing relative abundance during the period under consideration.

## 6.1 Impact of Continuous Trapping

The hatched blocks in figure A1.9 represent the periods of long term trapping that took place in order to suppress wild populations of G.palpalis in Tsakuwa (13 days) and Maisamari (35 days) prior to sterile male release.

### 6.1.1 Quantitative aspects.

In Tsakuwa pre-suppression monitoring showed an increase in relative abundance similar to Maikuya; during continuous trapping daily catch declined dramatically and by the end of the period daily catch had declined to 10-20 % of the first days catch - see figure A1.6.

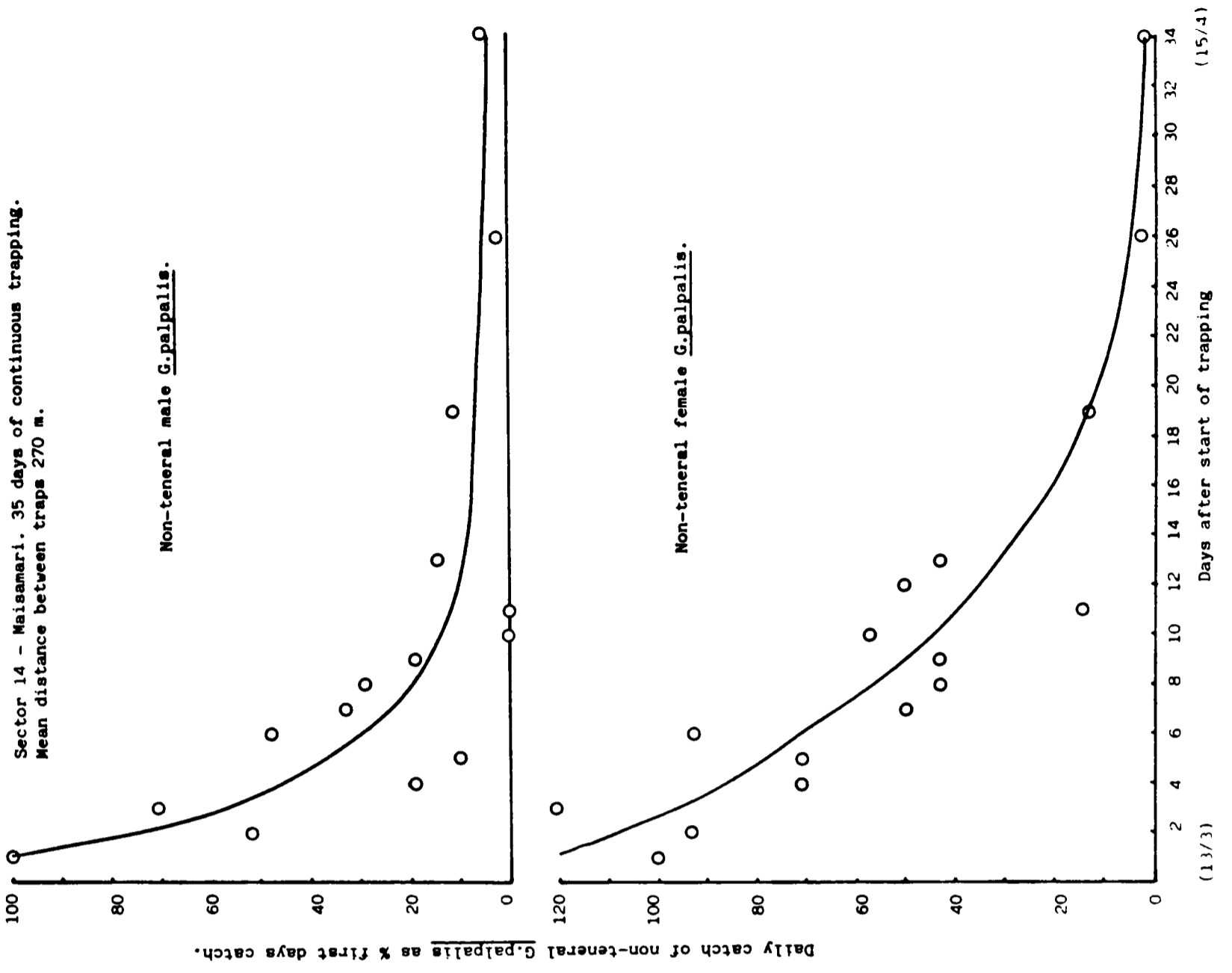
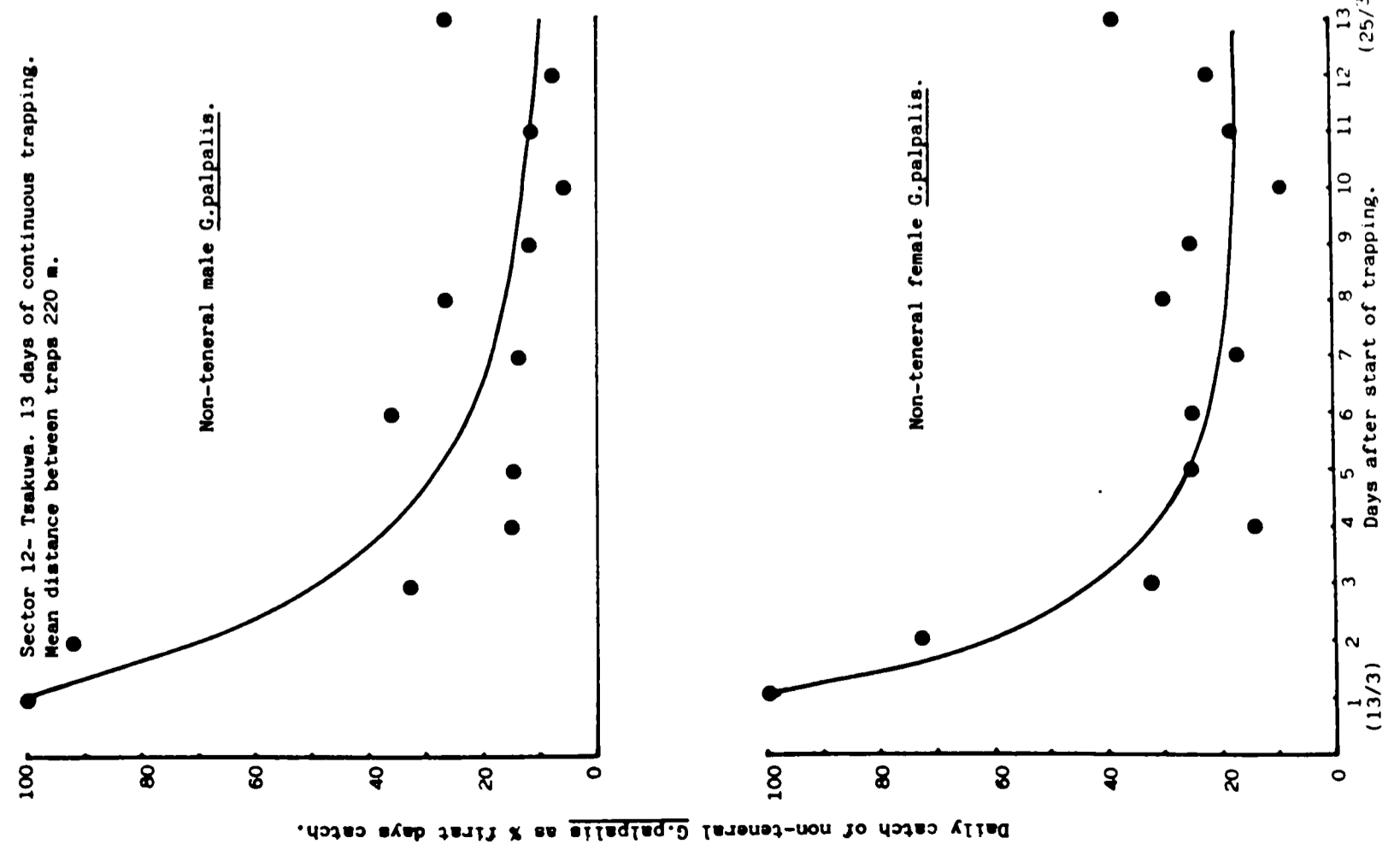
In contrast to Maikuya and Tsakuwa pre-suppression G.palpalis relative abundance in Maisamari appeared to be on the decline , and 35 days of continuous trapping reinforced this trend almost to the limits of detection with an overall reduction of 95% - see figure A1.6.

### 6.1.2 Qualitative aspects

In addition to substantial reductions in daily catch during long term trapping, marked shifts in the structure of the G.palpalis catch were apparent. Figure A1.7 shows the changing wing fray structure of the male catch, with increasing proportions of teneral and young flies, and the disappearance of wing fray categories 3 and 4, with prolonged trapping in Tsakuwa.

Similar increases in the proportion of teneral and younger flies were apparent in the structure of the female catch, based on the stages in ovarian development (figure A1.8). Mean ovarian age also declined steadily from 38 - 23 days over the continuous trapping period.

FIGURE A1.6 : PERCENTAGE REDUCTION IN DAILY CATCH DURING CONTINUOUS TRAPPING



Non-teneral female G.palpalis.

Figure A1.7

Changes in male wing fray structure of catch during continuous trapping. Sector 12 - Tsakuwa.

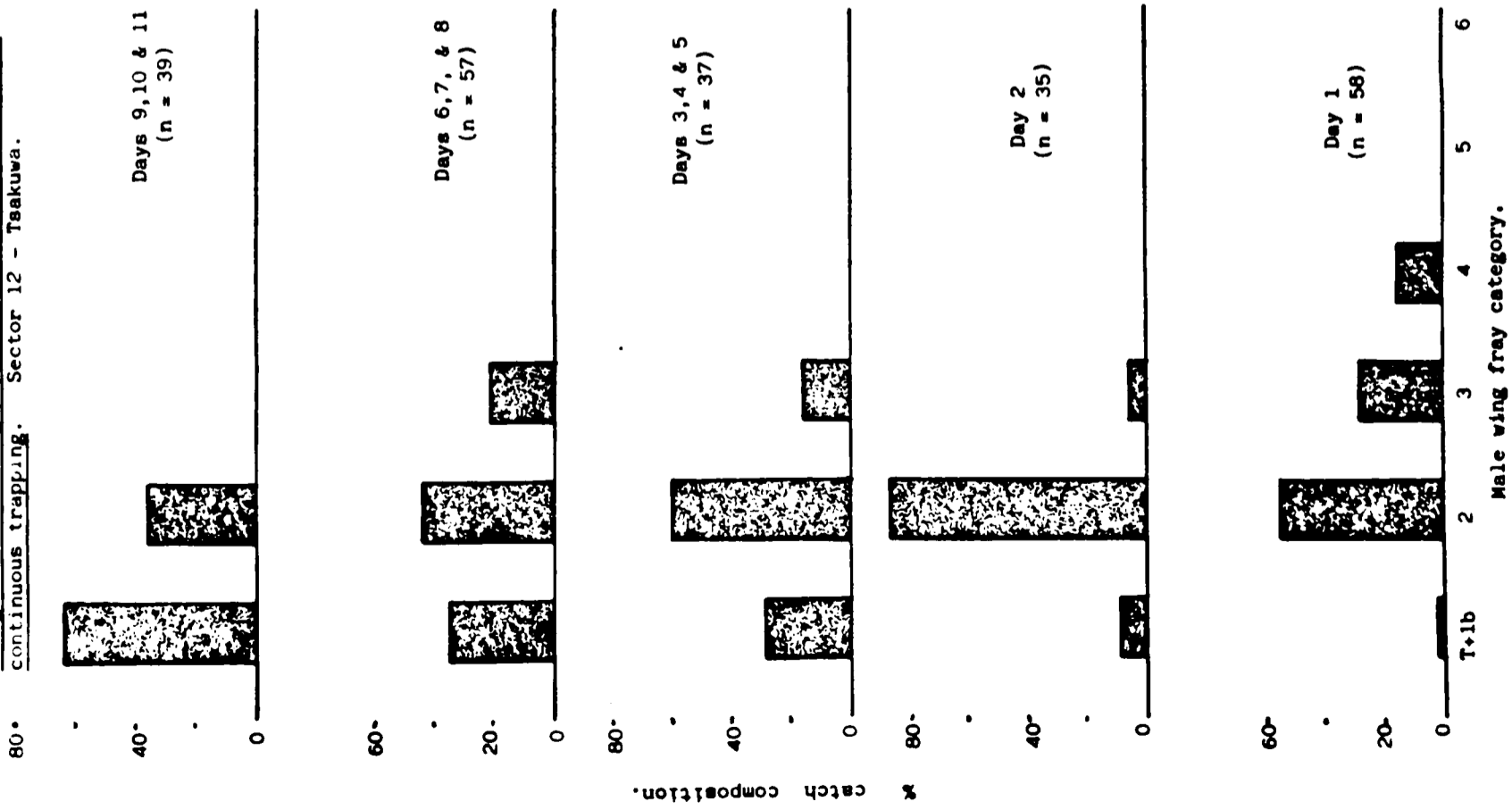
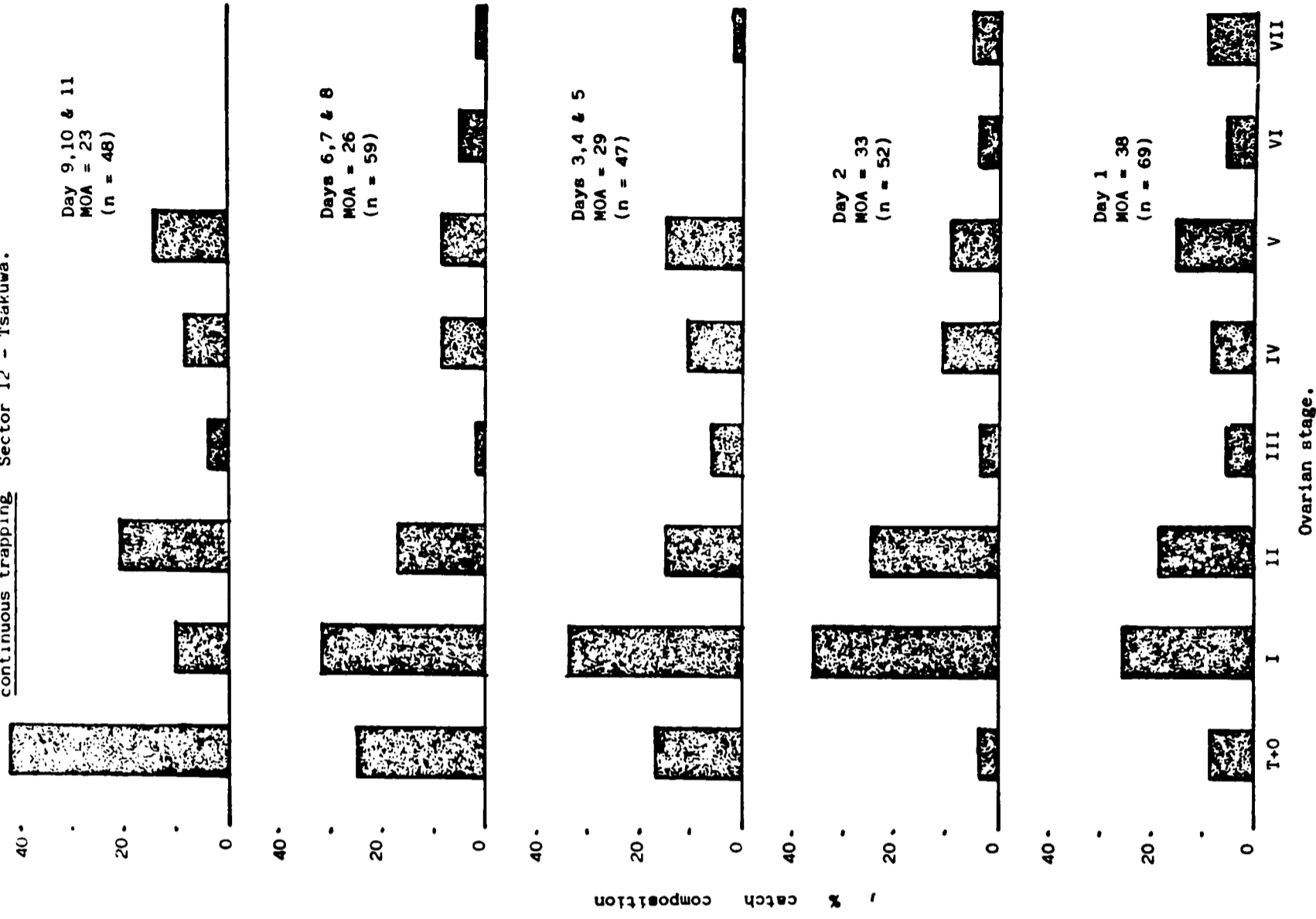


Figure A1.8

Changes in ovarian age structure of *C. palpalis* catch during continuous trapping. Sector 12 - Tsakuwa.



## 6.2 Impact of Sterile Males

The arrows in figure A1.9 indicate the sequence of sterile male releases in Kireyi, Tsakuwa and Kireyi forests; while the solid and dashed lines trace the relative abundance of G.palpalis during the first two months after the first release in Kireyi. Note however, that because of the the pre-release continuous trapping phases and the staggered timing of the releases the monitoring period shown in figure A1.9 covers only the initial six weeks after first release in Tsakuwa and the initial four weeks in Maisamari.

### 6.2.1 Quantitative aspects

In terms of relative abundance the release of sterile males was not expected to have any initial impact. In fact relative abundance appeared initially to increase after first release in the three forests. Three factors are believed to have contributed to this:

The underlying trend for relative abundance to increase during the period of study, as demonstrated in Maikuya.

"Bounce back" or recovery of the wild population after cessation of continuous trapping by replenishment/ emergence from pupal stocks still in the ground.

Unintentional release of unmarked sterile males which could not be differentiated from wild males. (See section 5.1)

Within the limited monitoring period covered by this report no clear impact of sterile male release on relative abundance can be discerned. In view of the length of the pre-productive period of females and the duration of the pupal period this is not surprising. For sterile males to have a detectable effect on population levels or relative abundance newly emerged females mated with sterile males must reach maturity (3 weeks) and one pupal period must elapse (a further 4 weeks).

The impact of continuous trapping in suppressing the adult population has already been described. The removal of adult females must reduce the rate of larviposition and in the longer term reduce the emergence rate. The initial increase in relative abundance of males and females after cessation of trapping in Tsakuwa, followed by a decline maybe considered to be a reflection of this delayed action effect.

### 6.2.2 Qualitative aspects

Despite the absence of quantitative evidence of the impact of sterile males on the wild populations, convincing evidence that they were indeed having a significant impact on female reproductive physiology was obtained.

Figure A1.10 shows the proportion of parous females in each forest island with empty uteri (solid circles) and which had experienced abortion (open circles), before and after the onset of sterile male releases.

Under natural conditions a small proportion of parous females within a wild population will have empty uteri, either as a result of recent larviposition or abortion; the rate of abortion depending on environmental conditions and the degree of stress experienced. Introduction of sterile sperm will disturb natural embryogenesis and increase the rate of abortion. However the distinction between abortion and post-larviposition, as made during the pilot release programme monitoring, was on the basis of relative ovariole size. It was therefore not possible to distinguish recent post-larviposition from earlier abortion.

Thus the impact of sterile males on reproductive physiology is best indicated by the proportion of parous females with empty uteri. Figure A1.10 clearly shows that soon after the release of sterile males in Kireyi, Tsakuwa and Maisamari, this proportion increased from less than 10% to between 30 - 50%. The number of viable pupae produced must therefore have been greatly reduced and a substantial reduction in emergence could be anticipated.

FIGURE A1.10 : PROPORTION OF PAROUS G.PALPALIS WITH EMPTY UTERUS

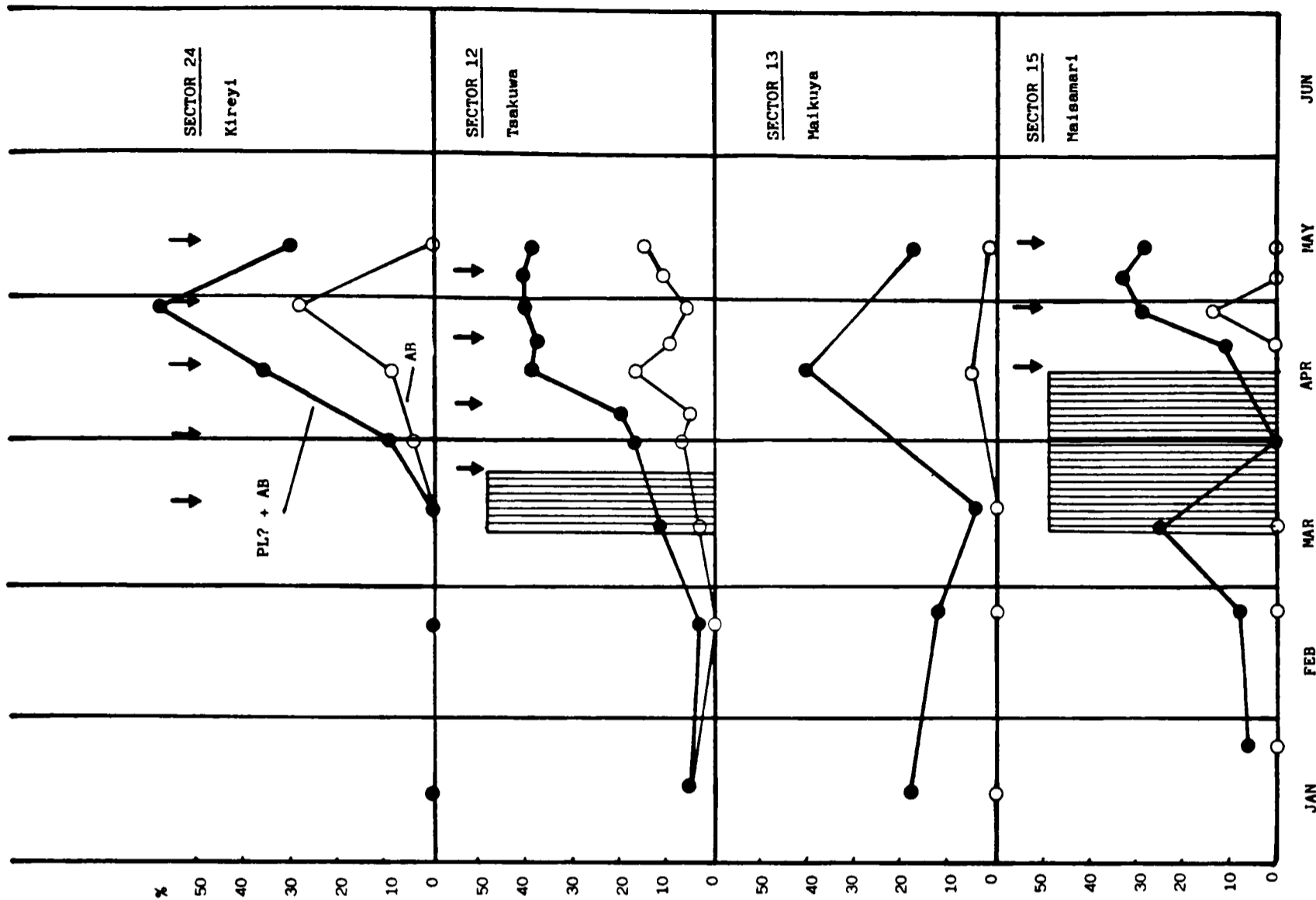
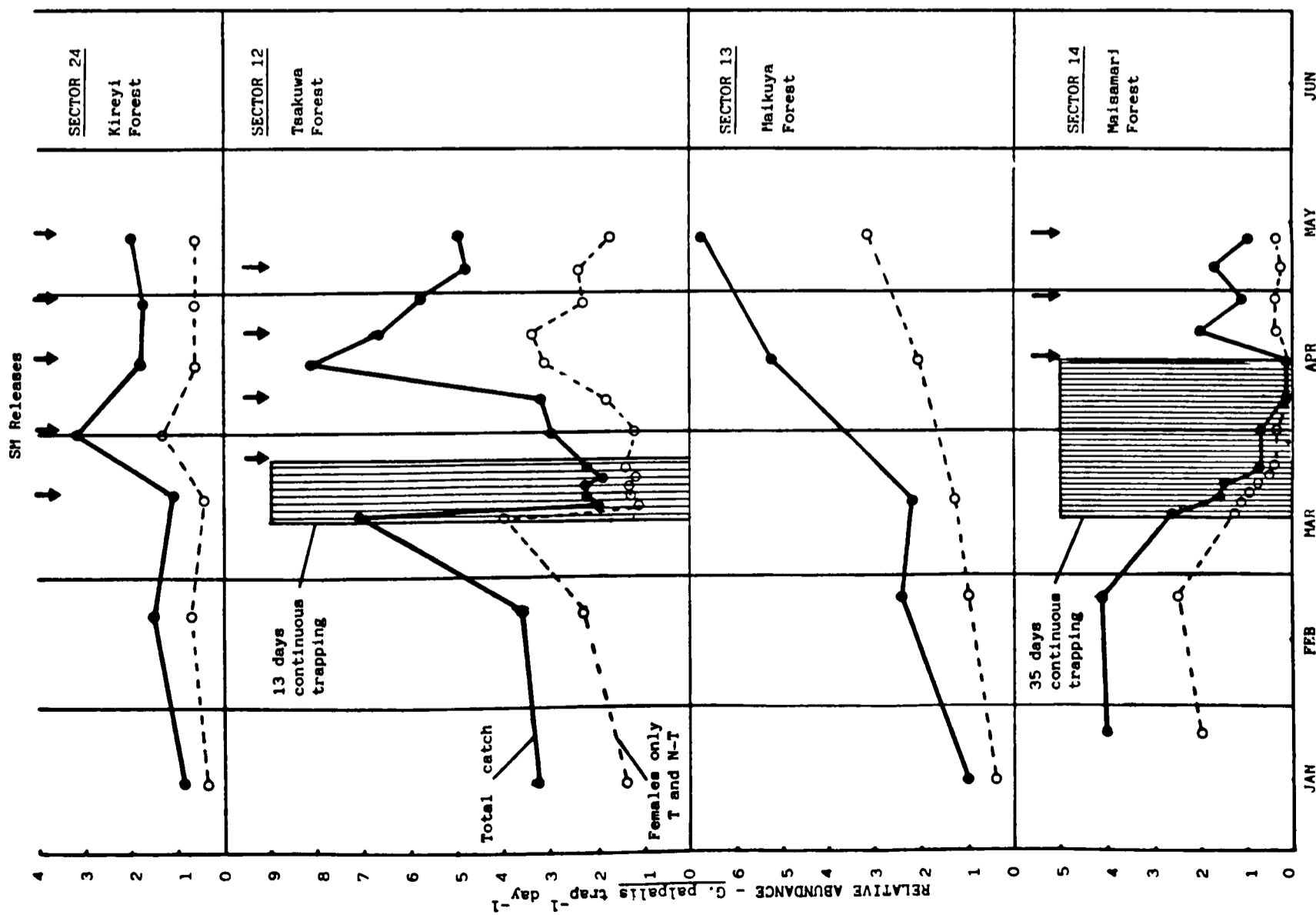


FIGURE A1.9 : RELATIVE ABUNDANCE OF G. PALPALIS



## 7 STERILE MALE RECAPTURE, SURVIVAL AND DISPERSAL.

In the previous section on tsetse population monitoring the changes in size and composition of the sample catch of wild G.palpalis that occurred after the release of sterile males were described. See figure A1.10 for changes in relative abundance and figure A1.11 for changes in the reproductive performance.

The observed impact on the wild populations is not only dependent on the number of sterile males released, but also on a variety of other factors including their survival and dispersal. Both are of major importance in determining the success, or degree of control achieved by the release of sterile males.

During the pilot release programme large numbers of sterile males were recaptured. From the colour and position of their marking it was possible to determine the time and place of their release, and thus how long they had survived, and how far they had moved. It must again be emphasised that the results described in the following paragraphs refer to data collected during the relatively extreme environmental conditions prevailing at the height of the dry season.

### 7.1 Overall Recapture Rate.

A total of 9592 sterile males were released from six points in Kireyi, Tsakuwa and Maisamari forests, during the first eight weeks of the pilot release programme. 1152 (12%) were recaptured during the first nine weeks following the initial release. Only 20 of these recaptures were taken by traps located in sectors different from that of release, (see table A1.7). 98.2% of recaptures were made in the same forest as release. Emigration during the height of the dry season can therefore be considered to be minimal. However 12 of the 20 inter-sector recaptures were obtained in the last two weeks of sampling, after the rains had broken and were from traps located at watering/crossing points. There is therefore a strong indication that intersector movement is likely to increase during the wet season and that it is related to the passage of livestock and people.

TABLE A1.7 : THE ORIGIN AND LOCATION OF RECAPTURED STERILE MALES

RECAPTURE SECTOR	RELEASE SECTOR		
	KIREYI 24	TSAKUWA 12	MAISAMARI 14
KIREYI 24	130	0	0
TSAKUWA 12	6	797	0
MAIKUYA 13	0	1	3
MAISAMARI 14	0	0	205
AKUNI 23	3	2	0
AKUNI 22	0	2	0
AGORI 25	1	0	0
RAFIN GOGO 15	0	0	2

The overall recapture rate of 12 % masks a considerable degree of variation from forest to forest and release to release. Recapture rates in Kireyi and Maisamari were generally low, ranging from 3 - 7 %; whilst those for Tsakuwa were considerably higher, 15-24% of sterile males originally released.

In part the variation maybe due to differences in sampling intensity - Kireyi was sampled for two days every two weeks, immediately before each release. However in Tsakuwa and Maisamari trapping intensities were similar - in both, traps were positioned 250 m apart and samples were taken for two days each week. The substantial differences in recapture rates between these latter two forests is most likely to be a function of differential survival of released sterile males.

## 7.2 Survival

Maximum recorded survival of sterile males during the pilot release programme was 27 days after release, but this of course gives no indication of the mean survival of the sterile males released. A measure of this can be obtained from the declining rate of recapture with time after a particular release.

The probability of surviving "p" until a given time "t" may be expressed

$$p = e^{-mt}$$

where "m" is the daily rate of loss.

The number surviving " $N_s$ " at a given time "t" after release of  $N_r$  sterile males may therefore be expressed:

$$N_s = N_r e^{-mt}$$

The number of trapped sterile male " $N_t$ " at a given time "t" days after release of  $N_r$  sterile males may be expressed:

$$N_t = aN_r e^{-mt}$$

where "a" is a constant, representing the efficiency of the arrangements of traps.

Converting this last equation to natural logarithms to the base "e":

$$\ln_e N_t = \ln_e (aN_r) - m.t.\ln_e e$$

Thus by plotting the number of recaptures to the base "e" on successive trapping occasions, a straight line should result, with a slope equal to the daily rate of loss, which will be the converse of the daily survival. Figure A1.11 shows the results obtained following three releases in Tsakuwa. Estimated daily loss rates ranged from 16 - 20 %. However these figures are based on the number of identified marked sterile male recaptures. As has been previously mentioned, a proportion (upto 12%) of sterile males were erroneously released without marks. Recaptures must therefore have been undercounted and daily loss rate overestimated. In addition daily loss rate includes an element of loss due to removal by trap sampling. Thus it seems reasonable to suggest that daily mortality of sterile males is likely to be in the region of 10 - 15 % (daily survival probability 85 -90 %).

### 7.3 Dispersal.

In previous sections of this report the catch of tsetse from each trap, within a given sector has been summed in order to give an overall sample for a particular occasion. In each of the release forests traps were positioned approximately 250 m apart within the central core habitat. By examining the number of sterile males recaptured by each individual trap at various distances from their respective release points a good measure of their dispersal can be obtained.

The problem with this is that to make any sense the analysis requires a large number of recaptures. The largest number of recaptures obtained from any one release was for release number 6 in Tsakuwa, in which 988 sterile males were released from release point 4, and 482 sterile males were released from release point 3. One week later a total of 228 of these sterile males were recaptured, and the following week a further 119.

Figure A1.12C shows the distribution of the sterile male recaptures, by trap, over the whole length of Tsakuwa forest, as a percentage of the total number recaptured from each release point, on the first trapping occasion which was days 5 and 6 after release. It can be seen that individual flies from each release point travelled virtually throughout the 5 km length of forest; but the bulk of recaptures were clumped around each release point - 75 % of recaptures being made within 500 m of release.

It is interesting to compare the distribution of recaptured sterile males with that of wild G.palpalis by the same traps at the same time. This is shown in figure A1.12B. The pattern is very different with a distinct trend for the number of wild males and females caught to increase towards the southern part of the forest (towards lower trap numbers.)

Figure A1.12A shows the ratio of wild to sterile males caught by each trap at day 5 and 6 after release. The mean ratio at that time was 1 wild male to 1.85 sterile males.

FIGURE A1.11 : SURVIVAL OF RELEASED STERILE MALES IN TSAKUWA FOREST

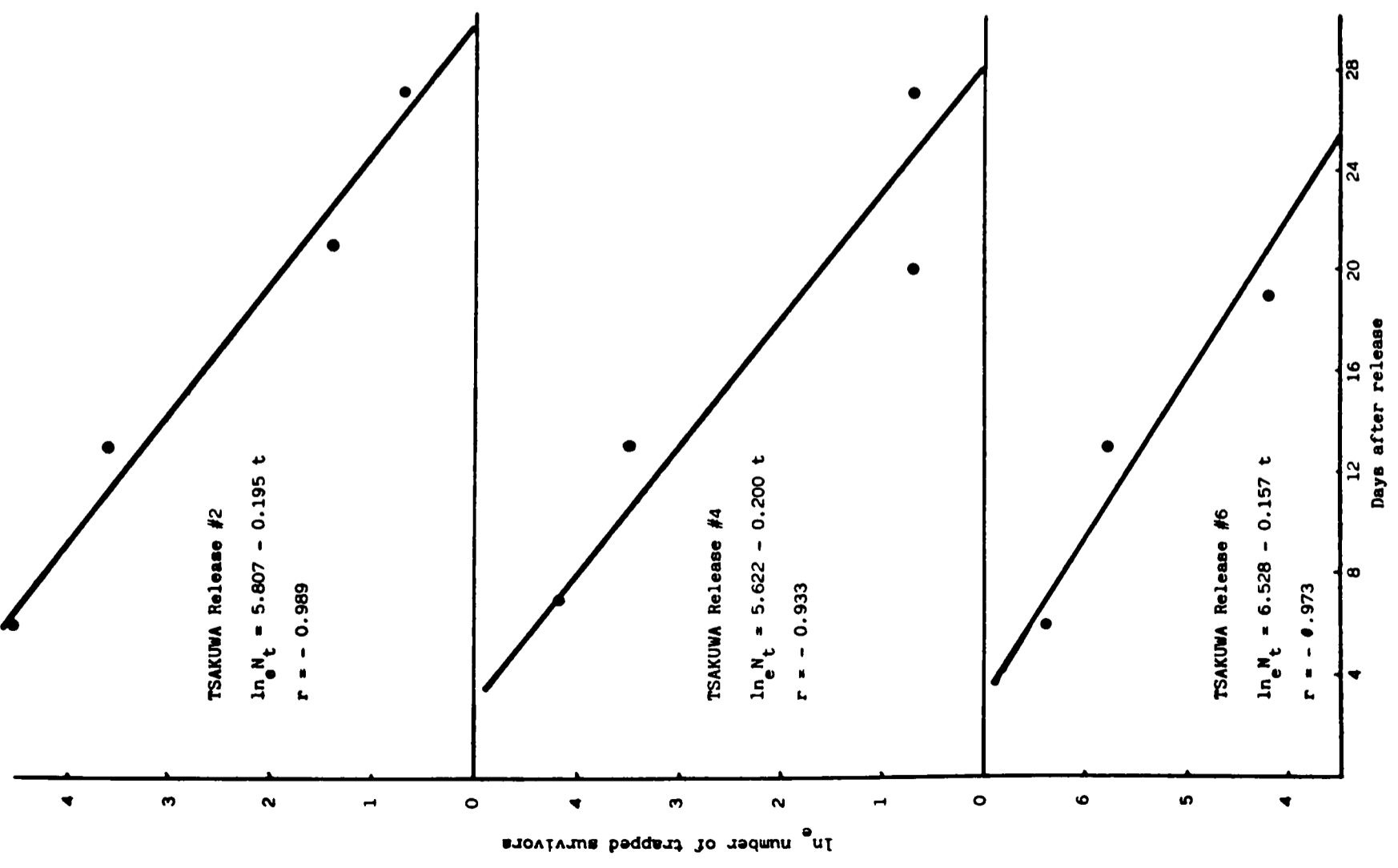
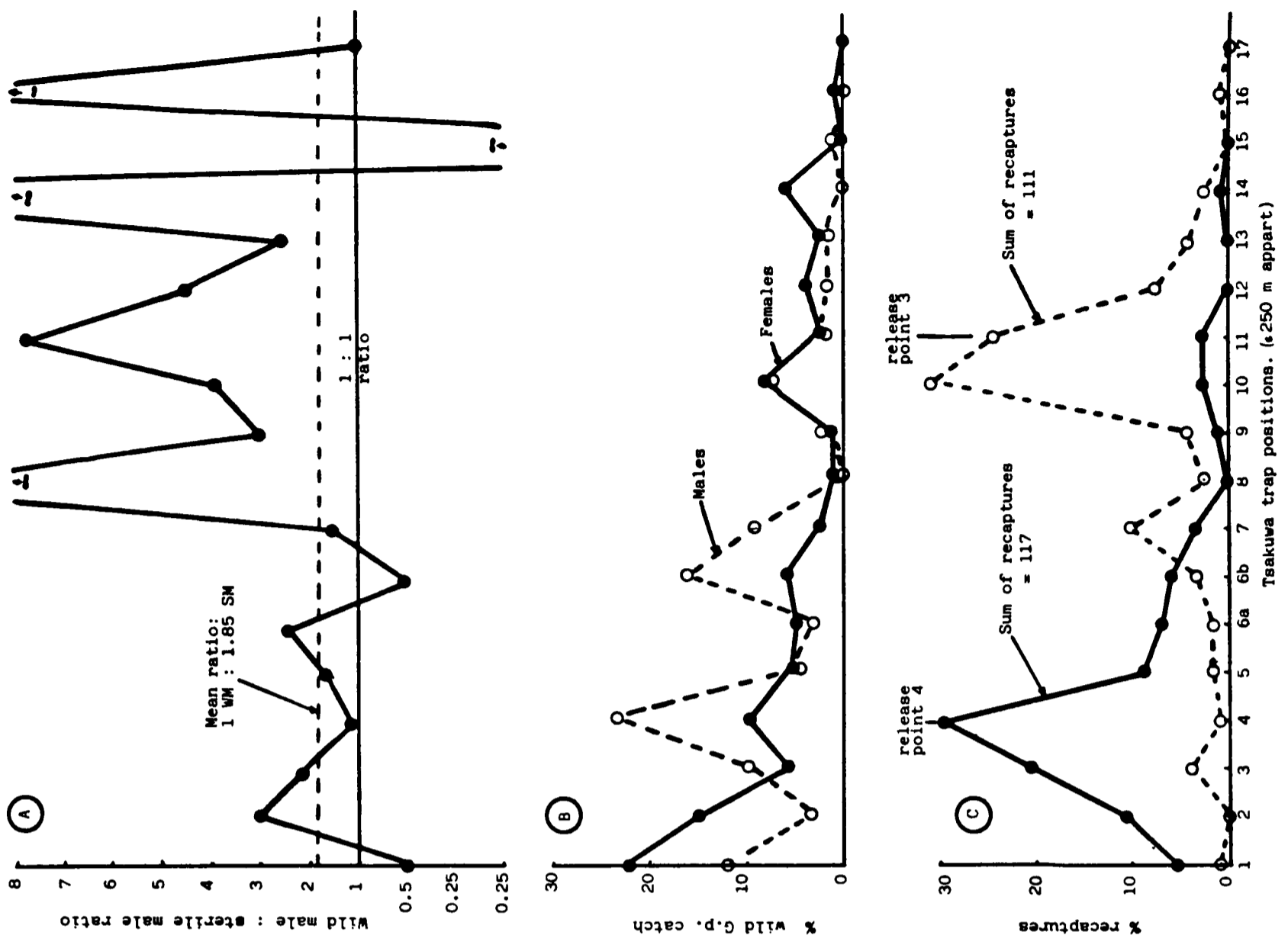


FIGURE A1.12 : DISPERSAL OF STERILE MALES AND RATIO TO WILD MALES IN TSAKUWA FOREST

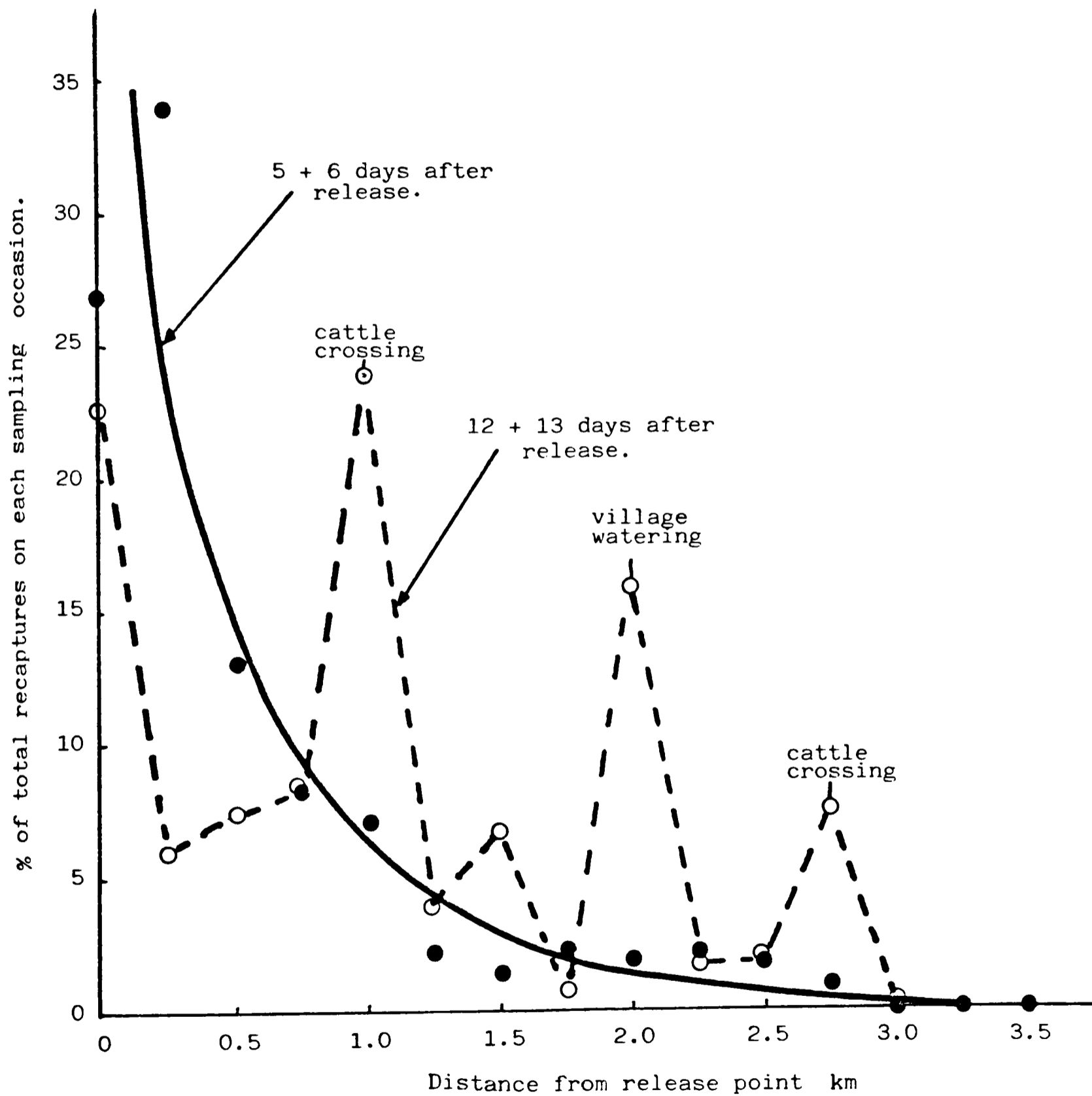


The distance moved by a sterile male must depend on its survival, for the longer it lives the more time it has to fly and the further away it can move from its point of release. On the first sampling occasion, 5 and 6 days after release the mean distance moved by all recaptures was 480 m; on the second sampling occasion, days 12 and 13 after release, the mean distance moved was 1020 m. From this one might imagine that the two recapture peaks shown in figure A1.12C were gradually spreading out and away from the release points to give a more uniform distribution. This however is not the case.

Figure A1.13 shows the percentage distribution of recaptures, in terms of the estimated distance moved from the point of release, based on a mean inter-trap distance of 250 m. The solid circles and line represent the distribution of sterile males 5 and 6 days after release, in which the percentage caught by each trap gradually declines with increasing distance from the release points. In marked contrast the open circles and dashed line show the highly irregular distribution with distance on the second sampling occasion, 12 and 13 days after release. The peaks correspond to cattle crossings, a village watering point, and of course at zero distance the release points.

A simple explanation for this change in distribution pattern is that during the first week after release sterile males gradually disperse, or diffuse, away from their release point, using up their energy reserves. Unless a host is found the sterile males are bound to die by day 10 (and probably much sooner). By the end of the second week only those sterile males which have fed during the intervening period will have survived, and be available for capture. In the virtual absence of wildlife, suitable hosts will only be found near cattle crossings or watering points. Hence the concentration of sterile male recaptures at the major cattle crossing and water points.

FIGURE A1.13 : CHANGES IN STERILE MALE DISTRIBUTION WITH TIME IN TSAKUWA



8 SUMMARY AND CONCLUSIONS.

This report describes the methodology and initial results of a pilot sterile male release programme carried out by the Nigerian project for the Biological Control of Tsetse over a four month period from January to May 1982.

The pilot release zone occupied a total land area of 170 km<sup>2</sup>, including 91 km of riverine forest covering some 1022 hectares, of which 777 hectares were wide forest and 235 hectares were narrow fringing forest habitat. Two species of tsetse were present: Glossina palpalis and G.tachinoides, the former being the target species.

Four semi-isolated G. palpalis populations within adjacent forest patches were the primary focus of attention. Pre-release sampling in January and February was followed by various levels of population suppression using biconical traps, prior to sterile male release in three of the four forest patches. No releases took place in the fourth forest, which was intended to be an experimental control.

During prolonged pre-release trapping substantial reductions in native adult tsetse populations occurred, which as anticipated began to recover on cessation of trapping because the duration of trapping had not exceeded the pupal period.

Following sterile male releases, which took place every two weeks, marked changes in reproductive physiology were observed with the incidence of empty uteri (resulting from abortion or recent larvaposition) rising from pre-release levels of 0 - 10 % to around 40 %. Thus strongly indicating that sterile males were having their desired effect, and that female reproductive potential was being reduced.

More than 11,000 sterile male G. palpalis were released over the nine weeks of releases covered by this report. Losses during transport over the 220 km journey from the laboratory in Vom to the release sites were satisfactorily low at around 5 %, with 95 % of flies dispatched being released.

Releases were made from two release points in each forest (1 - 2 km apart). Released sterile males dispersed well, with the mean distance moved five and six days after release being 480 meters; after 12 and 13 days the mean distance moved being just over a kilometer, with peak recaptures being made at cattle crossing and village watering points.

98 % of released sterile males were recaptured within the forest of their release. Towards the end of the period under consideration, when the rains had broken, a few recaptures were made at crossing points in adjacent forests, indicating that inter-sector fly movement was likely to increase during the wet season and that it was probably associated with the passage of cattle and or people.

Field cage survival observations of unfed sterile males showed a 75% survival to day 4 after release (day 5 after feeding) and that all flies were dead by day 9 after release (10 after feeding).

Survival probability of released sterile males was estimated to be in the region of 85 -90 % i.e daily mortality rate of 10 - 15 %. Maximum recorded survival was 26-27 days following release.

## 9 REFERENCES.

- BOURN. D. and M. OLADUNMADE, 1980. Eight areas in central Nigeria of potential interest for the biological control of Glossina palpalis palpalis using the sterile male release technique. 28 pp. Report to Federal Department of Pest Control Services, Kaduna, and the joint division of the Food and Agriculture Organisation and the International Atomic Energy Agency, Vienna.
- DENGWAT. L. 1981. A guide to the use of biconical tsetse traps in Nigeria. 12 pp. Federal Department of Pest Control Services, Biological Control of Tsetse Project, Box 76, Vom, Plateau State, Nigeria.
- F.A.O. 1982. Training manual for tsetse control personnel. Edited by J.N. Pollock. Published by Food and Agriculture Organisation, Rome.
- OLADUNMADE. M. and D. BOURN, 1981. Biological Control of Tsetse in Nigeria: present status of the field programme. 9 pp. Paper presented at First National Conference on Tsetse and Trypanosomiasis Research and Control in Nigeria. Kaduna 10 - 12 August 1981.

APPENDIX 2 TSETSE INFECTION RATES.

As part of the BICOT tsetse monitoring programme, periodic samples of tsetse were taken within the project area in order to determine the incidence of trypanosome infections. In conjunction with this work, a similar study was carried out in the adjacent Pandam Wildlife Park by Onah (1982). The results for the period January to May 1982, mid dry season to early wet season, are summarised in table A2.1, and make an interesting comparison.

Both studies used biconical traps for sample collection and used the same standard dissection technique (Baker, 1970) in which proboscis, midgut and salivary glands of non-teneral flies were examined for the presence of trypanosomes. The type of trypanosome infection being deduced from the observed sites of infection: T.(D.) vivax proboscis only; T.(N.) congolense proboscis and midgut; T.(T.) brucei proboscis, midgut and salivary glands; immature midgut only infections were assumed to be T.(N.) congolense infections.

The essential difference between the two study areas was that the BICOT collections were made from major riverine forest crossing points within a region of generally extensive cultivation containing substantial numbers of cattle, with habitats much modified by human activity; while the collections from Pandam Wildlife Park were from undisturbed natural riverine forest or lake shore habitats, where the influence of man was minimal, cattle were absent, but wildlife were present.

TABLE A2.1 TRYPANOSOME INFECTION RATES OF TSETSE CAUGHT WITHIN BICOT PROJECT AREA AND PANDAM WILDLIFE PARK.

SAMPLE SIZE including teneral	BICOT CROSSING POINTS				PANDAM WILDLIFE PARK										
	G. palpalis		G. tachinoides		G. palpalis		G. tachinoides		G. longipalpis						
	Males	Females	Sum	Males	Female	Sum	Males	Females	Sum	Males	Females	Sum			
	314	377	691	50	59	109	151	190	341	97	106	203	38	57	95
MEAN WING FRAY or MEAN OVARIAN CYCLES	2.9	2.4	-	2.4	2.1	-	3.1	3.0	-	2.6	2.1	-	3.1	3.4	-
INFECTION RATES															
<u>vivax</u> type	1.9	1.9	1.9	2.0	3.4	2.8	7.9	9.0	8.5	4.1	6.6	5.4	15.8	12.3	13.7
<u>congolense</u> type	1.9	2.7	2.3	0.0	0.0	0.0	2.6	3.1	2.9	3.1	4.7	3.9	7.9	10.5	9.5
<u>brucei</u> type	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.3	1.0	0.0	0.5	2.6	1.8	2.1
overall	3.8	4.5	4.2	2.0	3.4	2.5	11.3	12.1	11.7	8.3	11.3	9.9	26.3	24.5	25.3

A total of 1267 dissections of non-teneral individuals, representing three tsetse species, were performed. G. palpalis and G. tachinoides were common to both areas, while G. longipalpis was only found in Pandam Wildlife Park.

Highest overall infection rates were found in G. longipalpis, in which a quarter of all individuals were infected. The overall infection rates of both G. palpalis and G. tachinoides were two to three times greater in Pandam Wildlife Park, than at crossing points within the BICOT project area.

As expected from the differential development periods required for each trypanosome species, the incidence of T.(D.) vivax was much more common than T.(N.) congolense in all three tsetse species from Pandam Wildlife Park. In contrast, however, T.(N.) congolense and T.(D.) vivax infections were found in similar proportions in both G. palpalis and G. tachinoides from the BICOT project area.

The observed differences in infection rates of flies from the two areas might have been due to differences in the mean age of the samples. However, both wing fray analysis of males and ovarian age analysis of females, indicated that flies of the same species were of very similar age.

The results suggest that trypanosome infection rates of G. palpalis and G. tachinoides are reduced when wildlife is virtually absent, and cattle are the commonest host available. This is the opposite of the situation described for the Jebba to Ilorin cattle route by Jordan

(1964), Baldry (1969) and Riordan (1976), where exceptionally high infection rates were found in G. morsitans feeding exclusively on trade cattle.

One explanation for these contrasting findings may be that vector infection rates are very much dependent on the major host species present and their infection rates. (See Jordan, 1965a.) Trade cattle generally show a high incidence of trypanosomiasis, either as a result of the stressful conditions of their journey, which makes them more susceptible to infection, or because during their travel they are challenged by novel trypanosome strains, to which their immune systems are not adapted. Thus tsetse feeding on them must have a high chance of becoming infected. Many of the cattle within the BICOT project area, however, are believed to be resident all year round. Their immune systems would therefore be better adapted to local trypanosome strains, and their general plane of nutrition would be much higher than that of trade cattle.

The Nigerian Institute for Trypanosomiasis Research is currently investigating the incidence of trypanosomiasis in cattle within the BICOT area, and it is hoped that this work will elucidate the matter.

APPENDIX 3 TABLES OF VEGETATION AND LAND USE, BY SECTOR,  
WITHIN THE BICOT PROJECT AREA.

TABLE A3.1

EXTENT OF FOREST HABITAT*										
Sector	Name	Land Area ha	Narrow forest			Wide forest			Total Area ha	as % of land area
			Length km	Mean Width m	Area ha	Length km	Mean Width m	Area ha		
	<u>FEFERUWA CATCHMENT</u>									
1		2,450	12	20	24	9	79	72	96	3.9
2		2,750	30	20	60	7	71	48	108	3.9
3	Rafin Limbele	5,075	49	20	98	15	66	100	198	3.9
4		2,275	13	20	25	5	105	50	75	3.3
5	Feferuwa-downstream	3,350	28	20	55	13	77	100	155	4.6
6	Chiba	5,050	8	20	16	22	220	480	496	9.8
7	Ehula	6,900	4	20	8	28	182	500	508	7.4
8	Ganye-southern	2,700	9	20	18	15	134	195	213	7.9
9	Ganye-northern	1,750	2	20	5	10	90	94	99	5.7
10	Ohu-Feferuwa	3,000	22	20	45	2	51	12	57	1.9
11	Fadama-Gaudi	5,550	38	20	77	2	119	24	101	1.8
	<b>SUB-TOTALS</b>	<b>40,850</b>	<b>215</b>	<b>20</b>	<b>431</b>	<b>128</b>	<b>131</b>	<b>1,675</b>	<b>2,106</b>	<b>5.2</b>

\* Based on interpretation of 1972-74 aerial photography at a scale of 1:40,000.

TABLE A3.1 continued

EXTENT OF FOREST HABITAT *												
Sector	Name	Land Area ha	Narrow forest			Wide forest			Total Area ha	as % of land area		
			Length km	Mean Width m	Area ha	Length km	Mean Width m	Area ha				
	<u>AKUNI CATCHMENT</u>											
12	Tsakuwa (FPII)	1,575	0	-	0	470	5	215	215	13.7		
13	Maiakuya (FPIII)	1,200	1	20	2	480	3	160	162	13.5		
14	Maisemari (FPIV)	950	3	20	5	300	3	100	105	11.1		
15	Rafin Gogo	1,600	6	20	12	150	7	98	110	6.9		
16	Ashanga	1,300	6	40	23	68	3	20	43	3.3		
17	Ashige	3,125	7	40	27	86	10	89	116	3.7		
18	Assaikio	3,825	23	40	93	73	2	12	105	2.7		
19	Gidan Gambo	3,950	20	40	80	91	5	46	126	3.2		
20	Tuutu	2,725	26	20+40	85	-	0	0	85	3.1		
21	Sendem	11,475	86	20	172	124	4	47	219	1.9		
22	Akuni south-central	2,300	30	40	120	-	0	0	120	5.2		
23	Akuni Adogi	5,375	24	40	96	97	3	34	130	2.4		
24	Kireyi (FPI)	2,000	0	-	0	380	4	150	150	7.5		
25	Agori	1,550	0	-	0	120	2	20	20	1.3		
	SUB-TOTALS	42,950	232	20+40	715	194	51	991	1,706	4.0		

\* Based on interpretation of 1972-1974 aerial photography at a scale of 1:40,000.

TABLE A3.1 continued

EXTENT OF FOREST HABITAT *										
Sector	Name	Land Area ha	Narrow forest			Wide forest			Total Area ha	as % of land area
			Length km	Mean Width m	Area ha	Length km	Mean Width m	Area ha		
	<u>BOUNDARY CATCHMENTS</u>									
26	Akwenyi	12,025	50	20	100	0	-	0	100	0.8
27	Lake Feferuwa	7,375	7	20	15	40	163	661	676	9.2
28	Uga-Gwayaka	3,450	5	20	10	10	858	880	890	25.8
29	Rusu	8,925	35	20	70	31	87	270	340	3.8
30	Bechi-Ganye Ehela	6,100	53	20	106	32	63	203	309	5.1
31	Katari	4,100	6	20	12	24	61	148	160	3.9
32	Awuma	7,975	7	20	15	44	88	387	402	5.0
33	Ombi-Kurkyo	6,250	41	20	1	36	74	192	193	3.1
34	Amba	10,650	50	20	100	5	87	43	143	1.3
	SUB-TOTALS	66,850	214	20	429	222	125	2,784	3,213	4.8

	<u>OVERALL SUMMARY</u>									
1 - 11	Feferuwa catchment	40,850	215	20	431	128	131	1,675	2,106	5.2
11 - 25	Akuni catchment	42,950	232	20+40	715	51	194	991	1,706	4.0
26 - 3/4	Boundary catchments	66,850	214	20	429	222	125	2,784	3,213	4.8
	TOTAL PROJECT AREA	150,650	761	20+40	1,575	401	136	5,450	7,025	4.7

\* Based on interpretation of 1972-1974 aerial photography at a scale of 1:40,000.

TABLE A3.2

Sector	Name	PERCENTAGE LAND USE									
		UPLAND CULTIVATED	UPLAND UNCULTIVATED	WIDE FOREST	NARROW FOREST	DRAINAGE LINE	OPEN WATER	SETTLEMENT AND ROADS			
	<u>FEFERUWA CATCHMENT</u>										
1	-	65	27	3	5	0	0	0	0	0	0
2	-	36	57	0	4	1	0	0	0	0	2
3	Rafin Limbele	41	53	1	3	0	0	0	0	0	2
4	-	56	36	3	3	0	0	0	0	0	2
5	Feferuwa downstream	47	43	6	3	1	0	0	0	0	0
6	Chiba	54	34	8	0	0	0	1	0	0	3
7	Ehula	49	40	9	1	0	0	0	0	0	1
8	Ganye - southern	41	50	7	0	0	0	0	0	0	2
9	Ganye-northern	43	49	6	1	0	0	0	0	0	1
10	Ohu Feferuwa	53	44	0	1	0	0	0	0	0	2
11	Fadama Gandi	35	60	0	3	0	0	0	0	0	2

TABLE A3.2 continued

Sector	Name	PERCENTAGE LAND USE*									
		UPLAND CULTIVATED	UPLAND UNCULTIVATED	WIDE FOREST	NARROW FOREST	DRAINAGE LINE	OPEN WATER	SETTLEMENT AND ROADS			
	<u>AKUNI CATCHMENT</u>										
12	Tsakuwa (FP II)	58	26	15	0	0	0	0	0	0	1
13	Maikuya (FP III)	73	11	15	0	0	0	0	0	0	1
14	Maisehari (FP IV)	73	11	15	0	0	0	0	0	0	1
15	Rafin Godo	62	35	3	0	0	0	0	0	0	0
16	Ashanga	69	26	3	0	0	0	0	0	0	2
17	Ashige	67	18	9	2	0	0	0	0	0	4
18	Assaikio	66	31	0	0	0	0	0	0	0	3
19	Gidan Gambo	47	48	1	2	0	0	0	0	0	0
20	Tuntu	11	86	0	2	1	2	1	0	0	0
21	Sendem	20	79	0	1	0	1	0	0	0	0
22	Akuni south-central	37	62	0	1	0	1	0	0	0	0
23	Akuni Adogi	70	27	1	1	0	1	0	0	0	1
24	Kireyi FP I	29	65	5	0	0	0	0	0	0	1
25	Agori	43	51	6	0	0	0	0	0	0	0

TABLE A3.2 continued

Sector	Name	PERCENTAGE LAND USE*									
		UPLAND CULTIVATED	UPLAND UNCULTIVATED	WIDE FOREST	NARROW FOREST	DRAINAGE LINE	OPEN WATER	SETTLEMENT AND ROADS			
	<u>BOUNDARY CATCHMENTS</u>										
26	Akwenyi	10	90	0	0	0	0	0	0	0	0
27	Lake Feferuwa	39	38	12	1	0	0	9	1		
28	Uga - Gwayaka	12	44	37	1	0	0	5	1		
29	Rusu	47	42	2	3	1	1	2	3		
30	Bechi - Ganye - Ehela	53	36	2	5	1	1	0	3		
31	Katarl	56	38	2	3	0	0	0	1		
32	Awuma	63	23	10	3	0	0	0	1		
33	OmbiKurkya	70	22	4	0	0	0	0	4		
34	Amba	65	30	2	3	0	0	0	0		
35	Dep - Gwayaka	19	56	19	1	0	0	3	2		
36	Lake Pandam	21	58	8	2	0	0	8	3		

\* Based on interpretation of 1972-1974 aerial photography at a scale of 1:40,000.

#### APPENDIX 4 A SURVEY OF LAFIA FULANI.

This appendix summarises the results of a small sample survey by questionnaire of Fulani elders, owning cattle herds within the area of the Lafia Agricultural Development Project. It was carried out between 8 and 12 October 1979, and originally reported to the International Livestock Centre for Africa Sub-humid Programme (Bourn, 1979). The assistance of LADP's Grazing Reserve Officer Mohamed Mohamed, who acted as guide and interpreter, is gratefully acknowledged.

##### Summary of Findings .

##### Origins.

Only three of the 39 respondents considered the Lafia area to be their "home". None had been born there. The majority were born (64%), or considered their "home" (59%) to be in northern Kaduna state, formerly Katsina province.

##### Period of Association.

Although one of the respondents had first come to the Lafia area some 35 years previously, the majority (64%) had arrived in the period 1969 to 1974; with the greatest influx occurring in 1974, immediately after the Sahel drought which was felt most severely in northern Nigeria in 1972/73.

Wet and Dry Season Movements.

Only seven respondents (18%) had not moved during the previous year. The remainder (82%) had spent their last dry season in a different area. The majority having moved from dry season grazing areas to the south and south-west. Six respondents had moved as far as the banks of the Benue and beyond. Generally however, seasonal movements were not over great distances (measured in a straight line): 25% moving less than 10 km; 56% moving less than 40 km; and only 20% moving more than 100 km.

Future Intentions.

Except for those who did not move, all respondents intended to go back to the same general dry season grazing area they had used the year before; and all but two intended to return to the same wet season grazing area next year. The two exceptions said they would move elsewhere because of local conflicts with Tiv cultivators.

Personal Difficulties.

The respondents were virtually unanimous (87%) in agreeing that their greatest personal difficulties concerned conflict and competition with Tiv cultivators, who it was said: farmed on stock routes and "rugga" sites; blocked access to water; poisoned water holes; stole cattle; and caused fights.

Government Assistance.

When asked what the Government should do to assist Fulani, the three most common responses were: to establish grazing reserves (perhaps not surprisingly in view of the interpreters profession); solve the Fulani - Tiv problem; and improve water supplies in the dry season.

Cattle Disease.

The three most important cattle diseases were considered to be: Trypanosomiasis; Liverfluke infestations; and Blackquarter. (A veterinary survey of the incidence of various diseases would be of particular interest.)

Tsetse.

All respondents claimed to know of tsetse and reported their presence in a number of localities. The most frequently referred to being in the area of the Doma Forest Reserve and westwards to the Mada river; and north-east of Assaikio along the Dep river. However, it was evident from some of their descriptions that, at least amongst some of the respondents, there was some confusion between tsetse and other species of biting fly.

Explanation for Influx of Cattle During the Wet Season.

The results of this survey would indicate that the threefold increase in cattle numbers during the wet season demonstrated by the Lafia SE aerial surveys, is due largely to the movement of cattle into the area from dry season grazing areas further to the south and south-west, including trans-Benue movements.

A frequent complaint of both Fulani and resident village heads, particularly at Keana and at Adudu, was the shortage of water during the dry season. The soils of the zone covered by the aerial survey are derived primarily from sandstones and shales, which are notable for their poor water retention qualities. During the dry season water is scarce and the Fulani and their cattle therefore have to move out.

Questions and Answers.

Q. 1. How long have you been living in, or coming to, the Lafia area ?

Number of years	Year of arrival	Number of respondents	Percentage of respondents
1	1978	1	2.6
2	1977	-	-
3	1976	-	-
4	1975	3	7.7
5	1974	9	23.1
6	1973	3	7.7
7	1972	2	5.1
8	1971	3	7.7
9	1970	1	2.6
10	1969	7	17.9
11	1968	-	-
12	1967	1	2.6
13	1966	2	5.1
14	1965	2	5.1
15	1964	-	-
16	1963	1	2.6
17	1962	1	2.6
18	1961	-	-
19	1960	-	-
20	1959	2	5.1
.	.	.	.
.	.	.	.
35	1944	1	2.6
		39	100.1

Q. 2. Which area do you think of as home ?

Reply:	L.G.A.	State	Number	Percentage
Katsina*	?	Kaduna	13	33.3
Funtua	Funtua	Kaduna	3	7.7
Bakori	Funtua	Kaduna	3	7.7
Malamfashi	Malamfashi	Kaduna	2	5.1
Kancara	Malamfashi	Kaduna	1	2.6
Lagatchu	Zaria/Kachia?	Kaduna	1	2.6
Zaria	Zaria	Kaduna	1	2.6
Musawa	Kanyika	Kaduna	1	2.6
Lazuru	Sarminaka	Kaduna	1	2.6
Kano	?	Kano	5	12.8
Gulu	?	Kano	1	2.6
Lafia	Lafia	Plateau	3	7.7
Rekuba	Jos	Plateau	1	2.6
Sokoto	?	Sokoto	3	7.7

\*Reference to old province.

66.8% from Kaduna State.  
15.4% from Kano State.  
10.3% from Plateau State.  
7.7% from Sokoto State.

Q. 3. Where were you born ?

Reply	L.G.A.	State	Number	Percentage
Katsina*	?	Kaduna	13	33.3
Bakori	Funtua	Kaduna	4	10.3
Funtua	Funtua	Kaduna	3	7.7
Malamfashi	Malamfashi	Kaduna	2	5.1
Kancara	Malamfashi	Kaduna	1	2.6
Zaria	Zaria	Kaduna	2	5.1
Legatchu	Zaria/Kachia?	Kaduna	1	2.6
Musawa	Kankiya	Kaduna	1	2.6
Tsakiya	Dutsin-ma	Kaduna	1	2.6
Lazuru	Saminarka	Kaduna	1	2.6
Kano	?	Kano	6	15.4
Lokoya	?	Kano	2	5.1
Fanti	?	Kano	1	2.6
Sokoto	?	Sokoto	1	2.6

\*Reference to old province.

74.5% from Kaduna State.  
23.1% from Kano State.  
2.6% from Sokoto State.

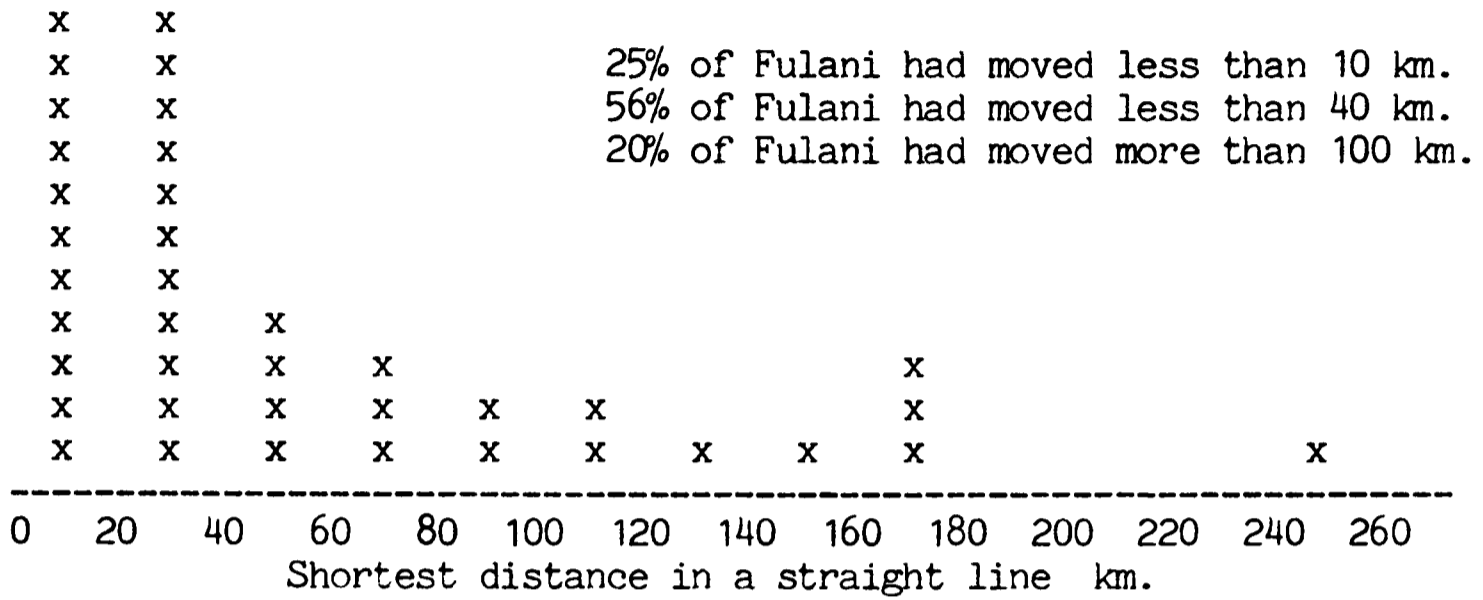
Q. 4. Where did you spend last dry season ?

Interviewed at:	Dry season spent at:	Shortest Distance	n
Adudu	Balanti, near Makurdi (BBB*)	85 km SW	2
	Udei	65 km SW	3
	Kadarko	50 km W	1
	Gidama Bawa	100 Km SW	1
	Keana	35 km SW	1
	Duduguru	50 km W	1
	Agyaragu	55 km W	1
	Assaikio	35 km NE	2
	Agvo	50 km SE	1
	Adudu (Had not moved.)	-	2
Keana	Udei	30 km SW	3
	Makurdi (BBB)	100 km SW	1
	Oturkpo (BBB)	250 km SW	1
	Udeni (BBB)	160 km SW	1
	Magabe	160 km SW	1
	Agwati (BBB)	120 km SW	1
	Gboko (BBB)	140 km SW	1
Akuruba	Agyaragu	25 km S	2
	Akunsan	10 km S	2
	Wakwa	5 Km S	1
	Bassa (near Keffi)	160 km NW	1
	Barakin Abdullahi	20 km NW	1
Akanga	Akanga (Had not moved.)	-	2
Gidan Maikuya	Gidan Maikuya (Had not moved.)	-	2
Assaikio	Assaikio (Had not moved.)	-	2
Dedere	Agyaragu	25 km W	2
	Obi	15 km SE	1

\*BBB: Banks of Benue and Beyond.

Most place names are to be found on the 1:250,000 SLAR Vegetation and Land Use Map. Federal Department of Forestry, 1976.

Frequency of distance moved from previous dry season to present wet location.



Q. 5. Do you intend to go back to the same area in the coming dry season?

Reply:	Number	Percentage
Yes	3	76.9
Yes, if dry season is long.	1	2.6
Yes, unless there are early rains elsewhere.	1	2.6
I don't move anywhere.	7	17.9
No.	0	-
	39	100.1

Q. 6. Do you intend to return to this area next wet season ?

Reply:	Number	Percentage
Yes.	29	74.4
Yes, unless there is disease.	1	2.6
I don't move anywhere.	7	17.9
No, because of conflicts with cultivators.	2	5.1
	39	100.0

Q. 7. The Government says that it wants to help Fulani. It has been saying that for a long time. What do you think the Government should do?

Reply:	Number	Percentage
Establish grazing reserves.	16	41.0
Solve Fulani - Tiv problem.	16	41.0
Improve water supplies.	15	39.5
Provide more drugs.	11	28.2
Control biting flies.	10	25.6
Improve animal health services.	8	20.5
Provide more treatment for trypanosomiasis.	6	15.4
Provide more treatment for streptothricosis.	4	10.3
Build rural animal health treatment centres.	2	5.1
Provide treatment for calf scouring.	2	5.1
Provide salt licks.	2	5.1
Provide zink roofed houses to live in.	1	2.6
Give assistance for settlement.	1	2.6
Provide supplementary feeding.	1	2.6
Traditional rulers should mediate in Fulani - Tiv conflict.	1	2.6

Q. 8. What are the greatest personal difficulties that you face ?

Reply:	Number	Percentage
Competition and conflict with Tiv.	34	87.2
Lack of stock routes to water and grazing.	15	38.5
Lack of water in dry season.	11	28.2
Animal health in general.	11	28.2
Ticks.	7	17.9
Biting flies.	6	15.4
Snake bites.	4	10.3
Streptothricosis.	1	2.6
Black quarter.	1	2.6
Too many other cattle in the area.	1	2.6
No suitable local area to settle.	1	2.6
Lack of adequate grazing area.	1	2.6
Having to move each dry season.	1	2.6
Other Fulani do not announce disease in their herds, and elders will not report outbreak to authorities.	1	2.6

Q. 9. Which of the following is the most important to you ?

Reply:	Number	Percentage
Finding food and water for your cattle.	25	64.1
Having schools for your children.	0*	-
Having hospitals to go to when ill.	0	-
Having somewhere for your women to sell milk.	0	-
Having somewhere to sell your cattle.	0	-
Having someone to treat sick cattle.	10	25.6
Would not answer: "There is no house without foundation; these matters can only be considered when one is settled".	4	10.3
	39	100.0

\*Two respondents were very much against the whole idea of schooling, for: "Who would then herd my cattle".

Q. 10. Which do you think is the most important cattle disease ?

Reply:	Number	Percentage
Trypanosomiasis. ("Samorin")	7	17.9
Liverfluke.	6	15.4
Blackquarter.	5	12.8
Calf scouring - worms.	4	10.3
Snake bites.	3	7.7
Streptothricosis.	3	7.7
Foot and mouth.	2	5.1
Biting flies.	2	5.1
Ticks.	2	5.1
Abortion.	1	2.6
No disease at the moment.	4	10.3
	39	100.0

Note: Some respondents wished to emphasise that they had sheep and goats as well, and that this should not be forgotten (!).

Up until this point in the questioning "tsetse" had not been mentioned by the interviewers. When asked:

Q. 11. Do you know of the tsetse (Hausa: kudan tsando; Fulani: mbubu silong)?

Everyone said that they did. However it was evident from their descriptions that, at least amongst some of the respondents, there was some confusion with other types of biting fly.

Q. 12. Which areas do you avoid because tsetse are present ?

Reply:	Number
Doma area, westwards to Mada River	12
Riverine areas in general.	7
North of Assaikio and around the Dep River	6
West of Makurdi-Lafia railway towards Doma forest.	5
Around Agyaragu.	3
South of Keana. towards the Benue River.	2
No flies in my area.	9

Many respondents said that although flies were present in certain areas, their cattle had to eat, and it was impossible to avoid them. Again the question of uncertain identification arises, and confusion with other biting flies is possible.