HABITAT SELECTION BY WEAVER BIRDS

IN THE

MIDDLE ZAMBEZI VALLEY

BY

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DECLARATION

It is hereby declared that this dissertation is my own work and that it has not been previously submitted for degree purposes to this or any other University.

Signed: ....

Date: ....

DEDICATION

To my wife Monde and to all my relatives and friends, as a little token of thanks for their support, in so many ways, throughout my work. Since no thanks could be sufficient, I trust this small mention at least records the depth of my gratitude.

APPROVAL

This dissertation of **Katanekwa Vincent Katanekwa** is approved as fulfilling part of the requirements for the award of the Master of Science in Ecology degree by the University of Zambia.

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ABSTRACT

This study explores the pattern of interactions between seven species of weaver birds viz: the White Browed Sparrow Weaver (Plocepasser mahali), the Spotted Backed Weaver (Ploceus cucullatus), Cabanis's Masked Weaver (Ploceus intermedius), the Masked Weaver (Ploceus velutus) and three species of Quelea between Chirundu and the Chongwe River on the Zambian side of the Zambezi Valley. The seven species were studied in relation to their spatial distribution in the area, habitat factors and food habits. The aim was to find out what influences their selection of particular habitats. A sample of 76 nesting colonies of the different weavers were described. 14 habitat and nesting colony features were measured and were analysed using principle component analysis (PCA). Food habits were determined by field observations supplemented by stomach content analyses of 50 collected specimens. A significant difference in the size of the seeds utilized by different species was found. Changing patterns of exploitation of resources were observed and their implications on land-use discussed.

14 morphological characters of the birds were measured and analysed using numerical taxonomic methods. Bill and toe measurements were related to habitat and food preferences. Selection of the different habitats by weaver birds was considered to hinge on three complementary selection pressures, arising from habitat structure, food and presence of nesting sites. During the breeding season the distribution of the weavers is also influenced by the selection of predator free space and this factor may be more influencial.

The weaver birds show different degrees of habitat isolation, varying from complete separation in Plocepasser mahali to differential

niche overlap in the *Ploceus* and *Quelea* species. All the weaver birds showed evidence of opportunistic feeding, overlaping in their use of seeds and other resources. The patterns of utilization of food resources depended on the abundance of food items at the time. Various adaptations such as flocking, habitat and dietary shifts, flexibility in habitat make it possible for the many similar species to occupy a limited and variable habitat without observable cases of direct competition.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the early years of this century animal ecology could have been equated to "Scientific Natural History" (Mac Fadyen 1963). It stressed the study of individuals, their distribution and life histories with occassional references to the environmental factors. At this early stage, naturalists were documenting subtle differences between related species. Gilbert White in 1789 noticed that the *Phylloscopus* warblers which were found in his parish, and were locally thought of as one species, were actually three species with three different songs and utilizing different parts of the beech woods. Another such early study is that of Joseph Grinell (1904, 1917) in which he gives an account of the differences in habitats occupied by the Chickadies (*Parus spp.*) in the boreal forests of north western Unites States, and between the Thrushes (*Taxostoma spp.*) of Southern California chaparral and desert edge.

It was not until Elton's book "Animal Ecology" was published in 1927, that the study of animal ecology shifted stress from the the organism to the population. The study of population dynamics allowed the making of quantitative statements about ecological phenomena. The models of Lotka and Voltera (1932 and 1926) were some of the outcomes of this shift. Between 1932 and 1959, most ecological thinking dwelt upon the "competitive exclusion principle". This came as the first verification of the mathematical postulations of Lotka and Voltera by Gause (1934). Most of the workers concerned with the explanation of animal speciation found an answer in this principle.

From 1931 to 1947 David Lack found much evidence of the competitive exclusion principle in birds. He first noticed aspects of habitat selection in the breeding birds of Breckland (U.K.), after which he did much work along similar lines in different places. During all this time it was becoming clear that the study of single species populations left many pertinent questions unanswered. The need to look at interacting assemblages of populations was slowly becoming obvious. In 1935, A.G. Tansley introduced the concept of ecological system (ecosystem) which was, in a way, a plea to people to consider organisms together with their environments (Sheail 1987). This was further developed by E.P. Odum in his book, "Fundamentals of Ecology" published in 1953, which influenced much of the ecological thinking and teaching on the American Continent.

In 1959, Hutchinson's question "Why are there so many animals?" crystallized the ideas of a community appraoch to the study of ecology which were simmering in ecological thinking for about two decades. This was a new appraoch that considered the community as a whole. Emphasis shifted to the study of the distribution of populations, the inter-relationships between the species and also the nature of the organisations of the natural community. Gradually a community structure begun to emerge which was comprised of patterns of resource allocation and spatial and temporal abundance of species. Central to all these facets of the community structure of animals, is the means by which species select their particular habitats.

At this stage it is necessary to define a number of concepts that will be used frequently in this dissertation and need clarification since no universally accepted definitions exist:

1. **Habitat Selection:** is the way in which organisms select the places in which they live.
2. **Community:** is an assemblage of species populations which occur together in space and time and functions as a unit (Odum 1971).
3. **Habitat:** is a collection of physical and biotic factors which together make up a place in which individuals in a community live and reproduce (Odum 1971). It is usually described by geographical, physical and biotic characteristics.
4. **Ecosystem:** this comprises the biological community together with its physical environment (Townsend et al. 1984).
5. **Niche:** is the role or place of a species in an ecosystem. It is the ultimate distributional unit of a species in a community describing how particular species relate to the other species, together with all the ecological factors, to form an enduring and functioning whole (Vandermeer 1972).

The occupation of a particular habitat by a species entails several consequences on the life of that species. Survival in that particular habitat is dependent on the way the species interact with each other within the community (Partridge 1978; Elton 1950; Mac Fadyen 1963). These interactions influence the behavioural characteristics, social organisation and patterns of resource utilization. The pattern of resource partitioning is determined by the various selection pressures to which each species is subjected. Since habitat factors are heterogeneous both in time and space, the species must adopt several survival strategies to enable it cope with any such changes (Southwood 1977). It is therefore understandable that species may be found in different habotats from season to season or even over longer periods. Minor differences in the habitat of the same species may lead to variations in some of their phenotypic and behavioural adaptations. Habitat selection, therefore, has ramifications in various dimensions of the ecology of the community and will form the main conceptual focus of this thesis.

Many studies have been done on habitat selection in Vertebrates. Simbotwe (1983, 1984) and Simbotwe & Garber (1979) investigated aspects of resource partioning among the lizard fauna of Lochinvar National Park Zambia. From their findings they deduced that the structure of the lizard community they studied was determined by the methods of resource partitioning obtaining there. Several other workers like Pianka (1973), Kiester et al (1975) and Schoener (1968) showed that the modes of feeding, resting and the nature of the nest site location in three species of Anolis lizards, could determine habitat selection. According to all these studies, habitat selection was directed towards the avoidance of competitition among related species of lizard; and also towards ensuring an adequate supply of food.

Kreulen (1975) found that the Wildebeest (Connochaetus taurinus hecki) on the Serengeti plains utilized the eastern and the central parts of the plains rather than the western part despite the similar vegetation in the two areas. The reason advanced for the selection was the acquition of an adequate supply of certain nutrients. The abundance of Hippopotamus (Hippopotamus amphibius) in the different parts of the Mara River was interpreted as reflecting habitat selection (Olivier and Laurie 1974).

Much of the work on habitat selection has been done on birds. Three types of approaches are apparent in these studies:

1. The **behavioural approach** which explores the patterns of habitat selection through the study of the behavioural adaptations of the different species.

2. The **environmental or quantitative approach** which tries to identify the different environmental factors which may act as cues to the birds when choosing a particular habitat. This method employs quantitative methods in the study of the different habitat factors.

3. The **evolutionary approach** which seeks to find out the different selection pressures leading to present distribution patterns through the study of phylogenetic genealogies.

The first approach stressed the role of behavioural adaptations as determinants of habitat selection. Lack (1933) contended that a bird responds to certain stimuli that lead it to settle in a particular location. Hinde (1956) and Partridge (1978) upheld the opinion that behaviour of the individual species dictates its habitat requirements and so, in a way, influences the selection of the habitat. Hilden (1965) separated the operational factors in habitat selection into two groups:

(i) the evolutionary factors: which can be defined as those factors of survival value to the species; and

(ii) the behavioural factors: these can be defined as those factors by which the birds recognise their habitat. In other words the behavioural patterns of any species are concerned with the choice of landscape and terrain, nest site, song, watch, feeding and drinking sites, and also with the availability of food, as well as with the other animals with which it shares its environmental.

The second approach to the subject sought to identify and quantify the environmental factors which could influence the occupation of a particular area by birds. Most of these workers measured the structural form of vegetation in habitats and correlated these with the diversity of bird species in order to identify the suitable habitats. Emlen (1956), proposed a method of habitat measurement that would make it possible to assess the selection pressures operational in a species. This approach got a further boost from Mac Arthur (1958) who demonstrated aspects of stratal selection among sympatric warblers in a coniferous forest. He showed that selection was based on nest height, vegetation densities, size of habitat and the availability of food. This study highlighted the role of resource partitioning in the structuring of a community. These findings and many others from similar studies led to the mushrooming of a new line of investigation which sought to establish the factors which make a particular place suitable for one species and not for the others (Poynthon 1962; Mac Arthur 1964; Bond 1957). Several other studies have demonstrated strong correlations between the structural features of the vegetation and the diversity of bird species (O'Connor 1981; Wilson 1974; Wiens and Rotenberry 1981). Multivariate statistical methods were employed to show the correlations between vegetation structural features and bird occupancy (Mac Arthur 1961, Kikkawa 1968, James 1971, and Mac Arthur et al 1966). Many other studies have attempted to show the relationship between both the diversity of habitats and that of bird species (Recker 1969; Cody 1968; Blake and Karr 1984; Martin 1960).

The third group are the evolutionists, who hold that the patterns of distribution observed at the present time are a result of various adaptations through which the species have passed in the course of their evolution (Lack 1971; Cody 1974; Wiens 1976). The adaptive significance of some of the behavioural patterns displayed by the different birds in relation to the environment supported these views (Moreau 1960). In some cases phylogenetic relationships were used to try and infer the origin of the various related species found in a similar habitat, taking into account aspects of convergent evolution and radiation.

Another facet to the study of habitat selection is the unravelling of the complexities of natural communities. Various interactions between the different species of birds in the same community have been investigated. Aspects of inter and intra-specific competition have been studied (Mac Arthur and Lavins 1967; Cody 1976 & 1978). Wilson (1974) observed that the diversity of species of birds is linearly correlated with folliage height diversity and that the productivity of a habitat showed no correlation to the abundance of biomass of birds. This study also showed that several selection pressures leading to the occupation of a particular site were responsible for the order observed in the community. The studies of Robins (1971), Robertson (1973), Anderson and Herman (1974), Cody and Walter (1976) and Edington and Edington (1972) demonstrated that related species use different parts of their habitats and thus are separated spatially.

The practical applications of these studies on habitat selection have been mainly in fields of conservation biology and in the management of ecosystems. The knowledge obtained from these studies have proved to be of considerable importance not only in the understanding of the life history of species, their adaptations and behaviour, but above all for systems of management of natural ecosystems and also in the field of pest control management. Benjamin et al (1984), and Blake and Karr (1984) have attempted devising habitat evaluation models which could be broadly applicable to a wide variety of habitats. Their ultimate goal was to define a few indices which would provide a good prediction of habitat suitability to wildlife as a whole.

1.2 SCOPE AND INTENTION OF THE STUDY

The present study investigates the different factors that may influence habitat selection by weaver birds in the Middle Zambezi Valley and considers their implications on the patterns of land use in the same area. In doing this an approach was adopted that can be considered as a synthesis of the most striking insights of the three approaches stated earlier.

A considerable amount of work has been done on the ecology, behaviour and breeding biology of some of the weavers (Collias and Collias 1959, 1963, 1969, 1971, 1978; De Camara Smeets 1980, 1981, 1982). These workers looked in detail at the nesting habits and breeding ecology of the Spotted-backed Weaver (Ploceus cucullatus) in particular. Crook (1960, 1964) surveyed the evolution and social organisation of the subfamily Ploceinae. He emphasised the role of behavioural adaptations in the maintenance of the social structure of the species. As a result of his work, a few revisions to the classification of the weavers were suggested. Moreau (1960) gave a comprehensive review of the taxonomy and classification of the subfamily Ploceinae. The most extensive coverage of the systematics and speciation of weavers is that of Chapin (1954).

The distribution of weavers has been documented by numerous workers such as Chapin (1954), Mackworth-Pread and Grant (1963) and Hall and Moreau (1970) on a continental level. In Southern Africa the works of Maclaclan and Liversidge (1971), Benson et al (1971), Dowsett and Aspinwall (MS) and Winterbotton (1978) are worth a mention. Generally weavers are described as being found in every type of country. They are widespread over the whole of the Afro-tropics. Their food habits range from the solitary insectivores like the Red headed Weaver (Malimbus malimbus) to the gregarious granivorous ones like the Quelea (Quelea spp.). Their breeding behaviour is dependent on the type of dispersion obtaining in the species. The solitary insectivores build single nests while the gregarious ones breed in big colonies (Crook 1964, Moreau 1960).

The Quelea have received more attention than any other of the weavers. Usually after breeding they congregate in big flocks, these may go into a gregarious phase in which they become an economic menance to farmers. This has led to the mushrooming of studies on the ecology and management of their populations. To date four international conferences on the subject of the ecology and management of Quelea have been held in Dakar, Senegal in 1955; in Livingstone, Zambia in 1957; in Bamako, Mali in 1960 and in Nairobi, Kenya in 1985. Several workers have addressed the subject of Quelea biology and ecology (Ward 1965a & b, 1966; Ward and Zahavi 1973; De Camara Smeets 1979, 1987). Among other things they looked at the significance of the flocking behaviour of Quelea.

The current shift in land-use patterns from hoe and axe subsistance agriculture to the creation of large, high level commercial agricultural schemes has inspired the study of the populations of the weaver birds in the Middle Zambezi Valley. The main aims of the study, therefore, were to investigate the distribution of weaver birds and the factors which may influence the selection of particular habitats. The study also attempts to assess both the implications of the distribution of weavers to the land-use patterns and the status of the weavers as agricultural pests.

1.3 PROBLEM STATEMENT

The fact that different species of weaver birds select different habitats is suggestive of some underlying factors which lead to the birds occupying these particular habitats. If one accepts the premise that organisms thrive best in their optimum habitats, then the problem is to identify the factors which determine these habitats. A habitat has been described above as a collection of species requirements for survival, incorporating not only factors such as, food, nesting sites hide-outs from predators but also interactions with other organisms. One may then ask what the main factors are which influence the selection of a habitat by a species. This aim may be more precisely stated in the form of four questions:

a. How are the different species of weaver birds distributed within the area?

b. Do they co-exist or do they segregate from one another?

c. What are the consequences of their distribution patterns to themselves and to the other animals of the area in general?

d. Are changes in the environment likely to affect them in any way?

1.4 ORGANISATION OF THE THESIS

The remainder of this chapter gives a concise account of the taxonomy and classification of weaver birds. Chapter 2 gives a description of the study area, including an account of the vegetation, climate, soils, geology and land forms. Chapter 3 presents the methods used in the field work and the tools used in data analysis. The results are outlined in chapter 4. Chapter 5 discusses the results in the light of current ecological concepts while chapter 6 gives an overview of the practical implications of the findings in the area. The numerical data giving the quantitative environmental factors associated with the nesting sites of weaver birds is appended to the text.

1.5 TAXONOMY AND CLASSIFICATION OF WEAVER BIRDS

The classification of the family Ploceidae is based mainly on the subjective evaluation of the plumage characters and of a few abitrary factors of the behaviour and ecology of the subfamilies (Moreau 1960). Much of the taxonomy of the family is based on the work of the early ornithologists like Sharpe (1890), Shelley (1905), Chapin (1917) and Sclater (1930) as recorded by Moreau (1960). The present widely accepted comprehensive classification is due to Sclater and Chapin.

The family Ploceidae was earlier divided into several subfamilies based on the similarities in their ecology. Roberts (1947) recognised seven subfamilies namely:

a. **Bubalornithinae** which contains the Buffalo weavers
b. **Plocepasserinae** containing the sparrow weavers
c. **Passerinae,** the true sparrows
d. **Sporopipinae** comprising mainly the scaly feathered Weaver finches
e. **Ploceinae,** the true weavers
f. **Estrildinae,** the waxbills
g. and lastly **Viduinae,** the parasitic whydahs.

These subfamilies have been maintained in the revisions of Robert's book by Mac Lachlan and Liversidge (1975). However, Chapin (1954) and Benson et al (1971) depart from this scheme by lumping the two subfamilies, the Plocepasserinae and Passerinae into the Passerinae. The Sporopipinae have been combined with the Estrildinae and raised in status to a family (family Estrildidae). This leaves four of the original subfamilies i.e. Bubalornithinae, Passerinae, Ploceinae and Viduinae. Of these the Passerinae and Ploceinae are considered to be the most advanced because of their accomplished skills in nest construction. Chapin (1954) is of the opinion that the subfamily Bubalornithinae should have been raised to an independent family. The Viduinae closely resemble the Estrildinae, the family of which they are nest parasites. They share curious mouth markings and the gape wattles of nestlings. However this could be an aspect of mimmicry only. One common feature that is shared by all the Weavers is the reduction of the tenth primary. This character is most pronounced in Passer and is, according to Chapin, an index of evolutionary progressiveness. Other characters considered in the classification are the modifications of the beak and other structures.

The family Ploceinae is represented by about 121 species in the whole of Africa. Out of these 45 species have been recorded in Zambia. About 21 of these are represented in the Middle Zambezi Valley (Dowsett and Aspinwall (MS), Benson et al 1971, Katanekwa and Siachoono 1985). Seven of the 21 species recorded were studied closely in this project.

All the names of birds used in this dissertation are as given in Benson et al (1971), "Birds of Zambia".

CHAPTER 2
STUDY AREA

2.0 NAME

The main stream of the Zambezi River can be divided into three stages. From the source up to the Victoria Falls (Musi-o-tunya Falls), the river develops from a juvenile stage up to maturity, giving the division referred to as the Upper Zambezi. The stretch between the Victoria Falls and the Mpata Gorge is known as the Middle Zambezi and the remaining stretch down stream of Mpata Gorge to the mouth is referred to as the Lower Zambezi. In the Zambian context, however, the upper and middle streches are sometimes referred to as the Upper and Lower Zambezi.

Downstream of the Victoria Falls the river flows through a series of gorges emerging at the Batoka Gorge from where the gorge spreads out into a valley commonly called the Zambezi Valley. In this study the area will be referred to in the regional context as the Middle Zambezi Valley.

2.1 LOCATION

The Middle Zambezi Valley, as defined in this study, lies between 28°50' to 30°30'E and 15°30' to 16°30'S. It is bounded between the Zambezi Escarpment along the 500m contour in the North and the Southern limit, which is along the international boundary with Zimbabwe lying in the Zambezi River Bed. The full stretch of the area extends from the Luangwa River in the East to Kariba Dam in the West (Fig. 1).

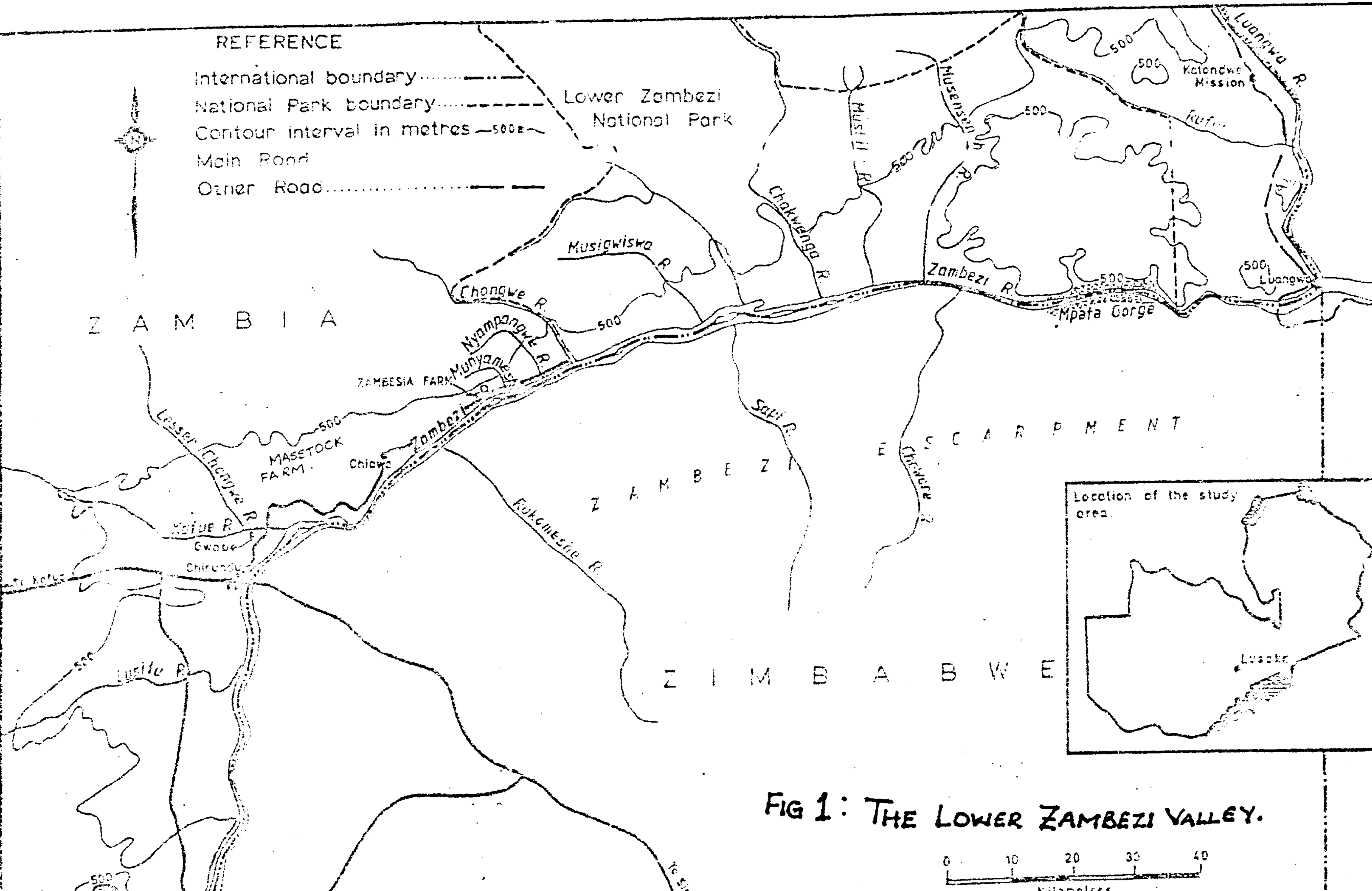
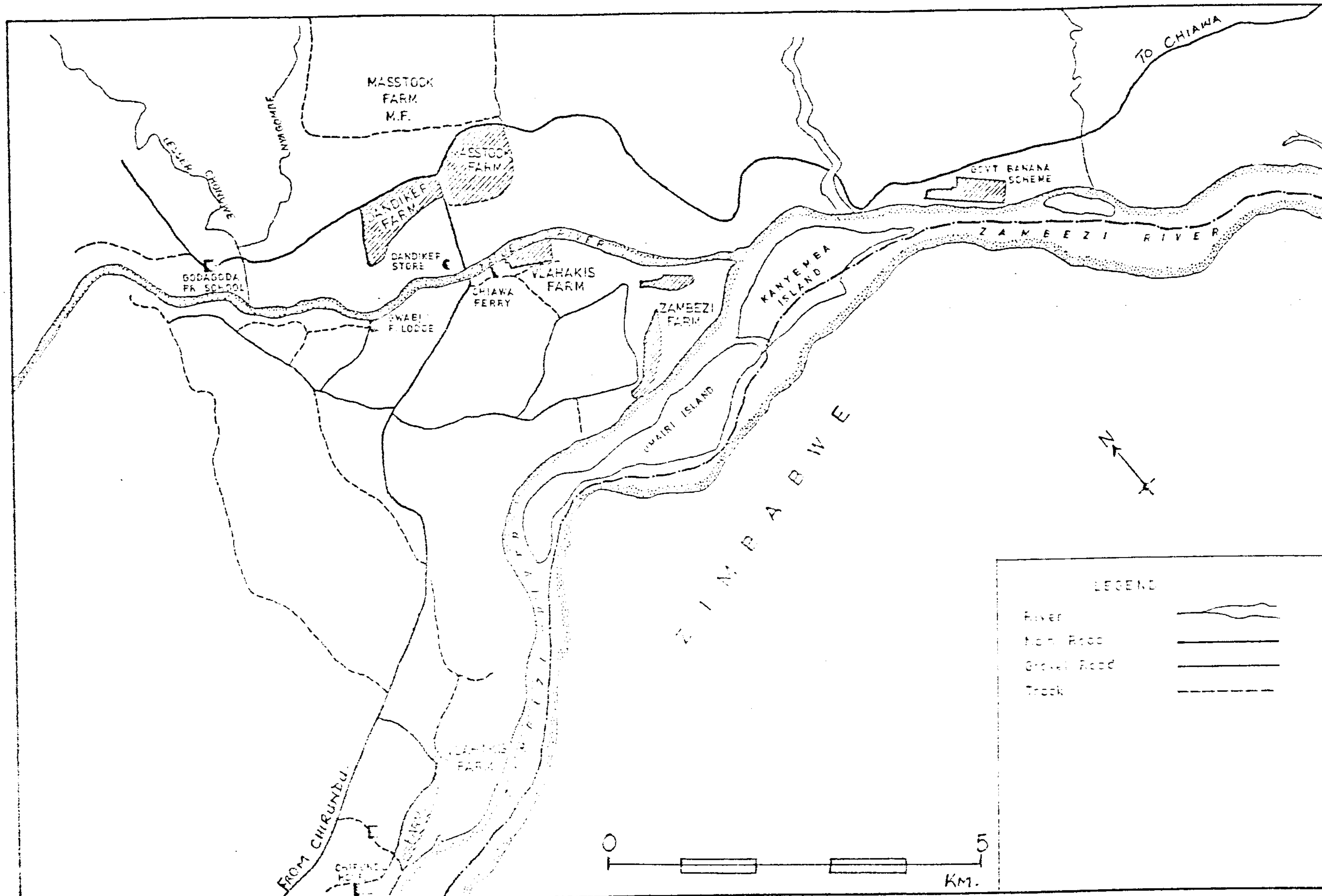


Fig 1: The Lower Zambezi Valley.



MIDDLE ZAMBEZI VALLEY STUDY AREA   FIG: 2.

This study was, however, confined to the area from Chirundu to the Congwe-Zambezi confluence, taking the full width of the valley on the Zambian side. Intensive work was limited to an area approximately 7Km in radious around Gwabi Fishing Lodge.

2.2 GEOLOGY AND LANDFORMS:

Very little has been published on the geology of the area. Most of what has been documented comes from Gair (1959). There is a general agreement among several workers that the oldest rocks in the area are those of the Precambian Basement forming the escarpment. These are mainly metamorphosed and deformed gneisses and paragneisses. The valley floor is underlain by Karoo sediments, products of fluviate aeolian deposition between Permian and Jurassic times (280-135 M.Y.B.P.) (Gair 1959). The upper Stormberg Sandstones of the Karooe sediments are overlain by the Batoka Basalts which terminated the Karoo sedimentary succession at about the same time (Cairney 1967). In some places these Basalts are broken by pre-Karoo ridges (Howard et al 1987).

The Zambezi River drops about 100m at the Victoria Falls and descends from 770m at the base of the Falls to about 490m at its entry into Lake Kariba. Its altitude falls further and reaches an elevation of 330m at the confluence of the Luangwa. The Valley trough is considered to be part of the East African Rift Valley System formed by faulting. The Escarpment is a deeply dissected, hilly country traversed by many ephemeral streams which flow in the wet season only. This is apparent from Chirundu to the eastern end of Chief Chiawa's area (Handlos and Williams 1985; Howard et al. 1987).

2.3 SOILS

A description of the soils of this area has been given by Henderson and Griffith (1959) on the Zimbabwean side of the valley and by Gair (1959) Cheatle and Wren (1985) on the Zambian side. All these descriptions were made on a reconnaissance basis. According to Cheatle and Wren (1985), most of the valley floor from Chief Chiawa to Mpata Gorge is covered with alluvial material and other soils of recent origin. The earlier workers on the other hand observed the following soils:

2.3.1 Sand Soils: The reddish soils derived from the aeolian sandstone of the Upper Triassic. These are deep, fine to medium grained sands. They have been highly leached of bases and are therefore acidic and have a low water capacity.

2.3.2 Colluvial Soils: These vary depending on the source and age of the deposited material. They are fertile, deep, chestnut brown soils with fine to medium grained loamy sands overlying sandy clay loams. They contain large calcareous concentrations derived from the basalts. They become much shallower near the escarpment due to the paragneissic stones.

2.3.3 Mopane Soils: These are fine textured clayey grey soils derived from mudstones embedded in sandstones. They overlie compacted, strongly alkaline horizons which are impervious. The high level of minerals rich in sodium in the mother sandstones contributed to the development of sodic soils in situ (White 1983). Mopane is the dominant vegetation on these soils, hence the name.

2.3.4 Alluvial Soils: These are found along the major rivers, i.e. the Chongwe, Lesser Chongwe, Kafue and the Zambezi. These vary in age, depth, texture and colour (Nuget 1982). The most recent deposits are clear white and generally sandy resulting in high permeability and poor water retention capacity when young. The older alluvia are similar to the soils of colluvial origin, being deep with a greater content of clay.

2.3.5 Rock and Rubble: As classified by Brammer (1973); These soils are derived from the most recent weathering of the rock substratum. They are often covered by thin layers of soil and are common on mounds and hills.

2.4 CLIMATE:

The Middle Zambezi Valley experiences an extreme tropical climate with three seasons, the wet-hot season from December to April, the cool-dry season from May to July and the hot-dry season from August to November.

2.4.1 Temperature: The area is denoted as the hottest part of the country with temperatures ranging from the mean lowest temperature of 6°C in the coldest month to the mean maximum temperature of 36.6°C in the hottest month. Extremely hot temperatures are experienced during the hot season when temperatures above 40°C are not uncommon. The highest temperature recorded during the study period was 43.8°C in the shade on 10th November 1988. The daily range of temperature is also very high with an average of 19°.

2.4.2 Rainfall: The area lies in the low rainfall zone, receiving moderate rainfall with an annual total between 400 and 700mm (Fig. 3). The humid period is restricted to the months of December through to February or early March. The season is very short with an average of 40 rainy days out of 90 days of the season. (A summary of the climate is given in the climatic diagram fig. 4).

2.4.3 Winds: The wind flow in the Zambezi Valley is predominantly easterly, with an east-south-east direction, because of the influence of the South-East Trades which prevail over the area. This general direction is maintained over 9 months of the year with very slight variation. During the rainy

Fig 3: RAINFALL TOTALS FOR THE MIDDLE ZAMBEZI VALLEY
(Compiled at Lusitu District Agriculture Office)

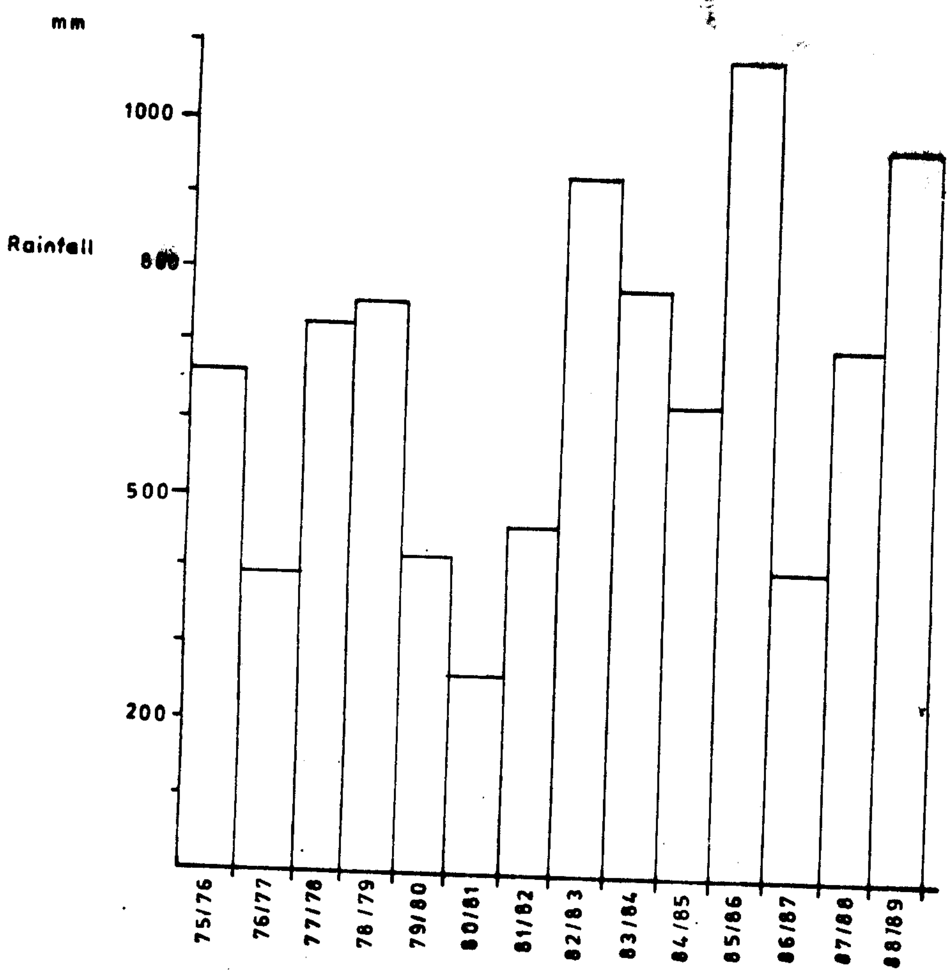
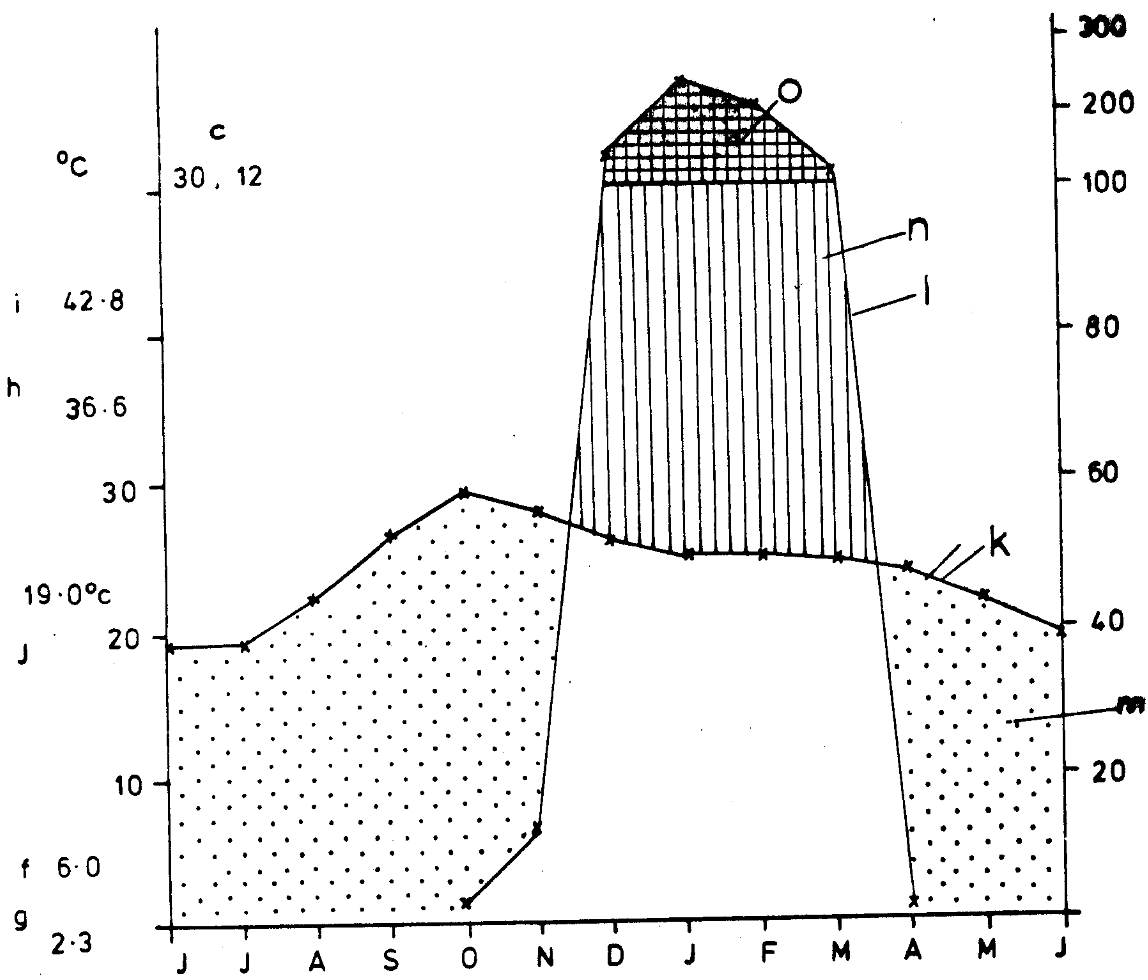


Fig: 4 CLIMATIC DIAGRAM FOR MIDDLE ZAMBEZI VALLEY

CHIRUNDU 392, 23·8°c, 662mm
(a) (b) (d) (e)



a. Station
b. Altitude
c. No. of years of observation
1st Temp. 2nd Rainfall
d. Mean annual Temp.
e. Mean annual rainfall (mm)
f. Mean daily minimum coldest month
g. Absolute minimum
h. Mean daily maximum hottest month.
i. Absolute maximum
j. Mean daily range of temp.
k. Monthly mean rainfall
l. Monthly mean rainfall
m. Arid period
n. Humid period
o. Per humid period mean ranfal

season the winds tend to be North-Easterly or even Westerly at times. An average wind speed of 3.7 knots has been recorded for Chirundu over a period of 7 years (Zimbabwe Met. Records). The highest speeds are recorded in September and October and the lowest during the months of December to April.

2.5.0 VEGETATION:

Early classifications of the vegetation of the area by Guy (1977) and Wild (1965) lump all the vegetation into two categories, the thickets and the mopane woodland. Later surveys on both the Zimbabwean and Zambian sides of the valley have shown this to be inadequate. Several vegetation types have been identified. Muller and Pope (1982) split these into ten different groups on the Zimbabwean side. Owing to the complex pattern of geomorphology and soils, the narrow width of the valley floor, human disturbances and a large number of ephemeral streams crossing the valley and the changing course of the Zambezi River, the vegetation on the Zambian side tends to be highly patchy resulting into what can be said to be a fine grained distribution (Howard et al 1987). The description given below is based on the works of White (1973), Fanshawe (1969), Du Toit (1983), The Zambezi River Basin Research Group and Muwowo (1989).

2.5.1 Mopane Woodland: These are woodlands in which Colophospermum mopane is the main canopy tree. They are associated with shallow poorly drained clay soils with a high content of sodium and also with poorly drained clay soils associated with the Kafue and Zambezi alluvial systems. The Mopane woodlands vary greatly in composition and structure depending on the quality and depth of soil on which they are standing (White 1973). The most common species associated with C. mopane are Commiphora mollis, C. africana, C. pyracanthoides, Kirkia acuminata and Boscia mossambicensis. The undergrowth is mainly composed of Croton menyhartii, Acacia ataxacantha, Boscia mossambicensis, Gardenia resinflua and grasses such as Panicum spp., Setaria spp., Digitaria spp. and a few others. The most common of the creepers is Fockea multiflora.

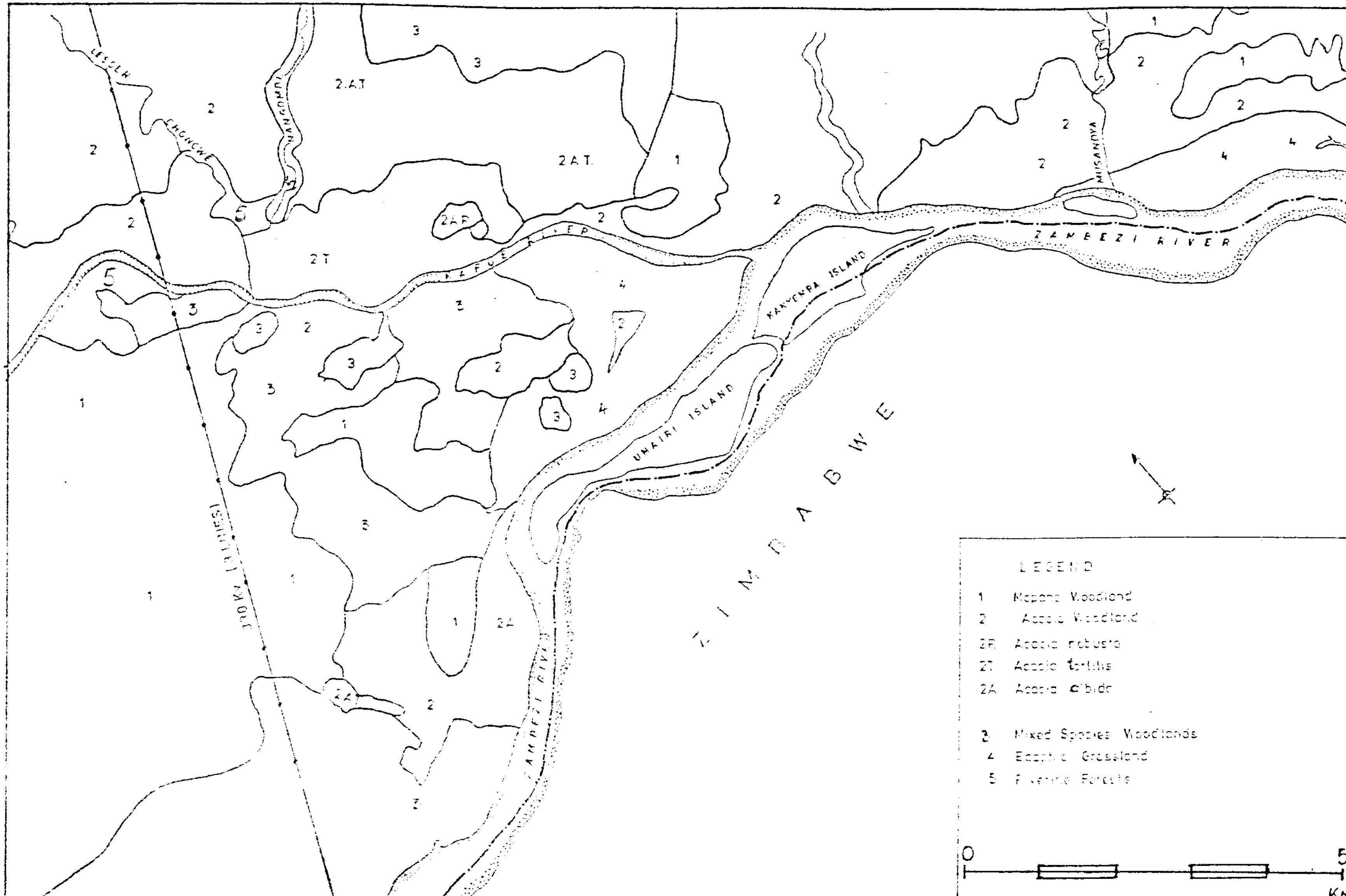
2.5.2 Acacia Woodland: Acacia woodlands are often named after the dominant species. Generally these woodlands are found on the flood plains, in low seepage areas and the colluvial deposits. The most common are the Acacia Albida woodlands on the flood plains of the main rivers and the Acacia tortilis woodlands on the colluvial deposits associated with the old flood plains. A. tortilis has two ecological forms in the valley the tall trees with flat umbrella shaped canopies on the richer soils and the shruby form on the shallower soils. Acacia robusta is a little different from all the others as it varies greatly in location. In some areas these woodlands may be in combination with the following species; Lonchocarpus capassa, Cordyla africana, Ficus Zambesiaca, Dichrostachys cinerea, Capparis tomentosa, Diospyros senensis and Combretum eleagnoides. The undergrowth is rather sparse. The main species found are the Solanum spp.; Cassia spp., Boscia spp., and Melua spp. The common grasses are Digitaria spp; and Hyparrhenia spp. In places which become water logged Echinocloa spp. and Rottboellia spp. are also common.

2.5.3 Mixed Species Woodlands and Thickets: It is assumed that these woodlands are remnants of the original vegetation, which through human interference, fires and grazing have been altered with many of the understorey species becoming the dominant ones. Typical trees of this vegetation are Sterculia quinqueloba, Commiphora mollis, Pteleopsis myrtifolia, Dalbergia nyasae and Lonchocarpus capassa commonly found on slopes. Species such as Kirkia acuminata and Afzelia quanzensis favour seepage areas. In areas with relatively deep sands dry deciduous forms of this vegetation show very close affinity to the Baikiea plurijuga forests in Western Zambia though without the Baikiea itself. Common species in these woodlands are Pterocarpus lucens antunesiee, Kirkia acuminata, Commiphora karibensis, Pteleopsis myrtifolia, Xylia torreana, Pteleopsis anisoptera, Lonchocarpus bussei and L. capassa. The undergrowth is generally composed of the following species, Combretum celastroides, C. eleagnoides, Friesodielsia obovata, Acacia ataxacantha and Grewia flavescens olukondae. Shrubs of Combretum mossambicense, Vangueria infausta, Holmaskioldia tettensis and Croton scheffleri are also not unusual.

2.5.4 Grassland: The main grassland is confined to the Zambezi flood area. The common grasses in these places are Eragrostis viscosa, Panicum spp, Setaria spp, Rottboellia sp, Echinocloa sp, Soghastrum sp, Digitaria spp, Brachiaria spp.

2.5.6 Riverine Forest: Very few patches of this are found on the Zambian side. The common trees in this vegetation type are: Tamarindus indica, Garcinia livingstonei, Acacia albida, Cordyla africana, and Piliostigma thoningiee. The shrubs include Combretum mossambicense, C. obovatum, C. paniculatum, C. microphyllum and Dichrostachys cinerea, **Friesodielsia** obovata and Grewia flavescens olukondae.

The above account covers the full stretch of the valley though only those species which were common in the area where extensive work was done are included. The spatial distribution of the different vegetation types in the study area is described in Fig. 5.



CHIRUNDU-CHIAWA STUDY AREA: VEGETATION MAP FIG: 5

CHAPTER 3

METHODS

Field work was conducted from November 1988 to May 1989. Initially a general avian survey of the area was carried out. This was followed by the sampling and monitoring of the different habitats and nesting colonies. During this period, a total of 96 nesting colonies were noted in the area, 76 of which have been described in this study.

3.1 GENERAL AVIAN SURVEY

Different survey methods have been devised and described by various workers (Emlen 1971, Krebs 1971, Pianka and Huey 1971, Anderson 1982, Mac Arthur et al 1966, Benjamin et al 1984, Karr and Roland 1971, Scott et al 1981). All these have minor differences in detail and emphasis. The transect method as described by Emlen (1971) and the spot mapping method by Krebs (1971) were adopted with slight modifications for this survey.

To start with the area was covered systematically by vehicle, recording all places in which signs of occupation by weaver birds were seen. About 33 such places were recorded. Three line transects were laid down in these places and all the weaver birds seen were recorded. In places where visibility was limited by thick vegetation, mistnets were set. Mistnet paths about 1m wide and approximately 30m long were cleared. Two mistnets, one 20m and another 10m long, were set in one path. The mistnet paths were places adjacent to each other about 20 to 50m apart.

3.2 HABITAT DESCRIPTION

A habitat description format that allows for a rapid, yet fairly detailed and consistent assessment of habitat features in the field was developed. Six types of habitat information were recorded, i.e. general description of the area; phenology of selected plant species; information on vegetation structure and floristic composition around the nesting colonies; measurements of diameter; distances between the trees and estimates of the crown cover and height. These have been recommended by several other workers (Emlen 1956; Anderson 1982; Janees and Roland 1971; Rosenwelg and Winaker 1969).

Vegetation structure and floristic composition were sampled around the nest colonies using the releve method (Mueller-Dombois and Ellenberg 1974). No quadrats of fixed size were used. Instead the area sampled was determined by the nearest neighbour measurements. The mean nearest neighbour distance was the radius of the area sampled. The height of the different layers and the vegetation cover were estimated by visual approximation. The height was recorded in three classes: tall stature > 10m, medium stature 5-10m and low stature 1-5m. The percentage cover of the different layers was given in the following classes: Closed canopy > 60% cover, open canopy 25-60% cover, scattered trees 5-25% cover and very scattered trees < 5% cover. The phenology of the vegetation was simply noted as green, flowering or fruiting, depending on the condition at the time.

The crown cover was calculated from measurements of the crown diameter. This was measured on the ground from the edge of the perimeter of the crown through the center to the other side. Two measurements of the diameter were made to give two diameter measureemtns D1 & D2, at right angles to one another. The crown cover (CC) was calculated as follows:

$$CC = ((D1 + D2)/4)^2$$

The height of the canopy was estimated by triangulation using an Abney spirit level as described by Brower and Zar (1982). The height was calculated as follows:

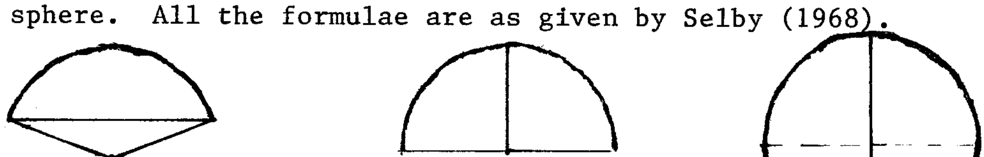
$h = D.\tan a$

or $\tan a = h/D$ where H is the crown height

D is the distance from the tree

a is the angle of inclination

The crown cover and the height were used to derive the foliage volume. The calculations were based on a model of a truncated sphere. All the formulae are as given by Selby (1968).



b a c

(a) When $h = a$ $Cv = 2/3\,\pi a^3$

(b) When $h < a$ $Cv = 1/6\,\pi h(3a^2 + h^2)$

(c) When $h > a$ = $Cv = 4/3\,\pi a^3 - (1/6\,\pi(2a\ h)(3a^2 + (2a - h)^2))$.

The nearest neighbour method was used in the estimation of the frequency of the tree species. All the distances were measured from the next tree to the nearest two trees in the four different quadrants of the compass. A tree was considered to be any woody species with a circumference of 30cm or more at Knee height. The circumference at breast hieght of all the trees to which the distance measurements were taken was also recorded.

The density of the tree species and the basal area were calculated from the mean nearest neighbour distances and the circumference at breast as described by Pielou (1971), Clark and Evans (1954) and Southwood (1978) respectively. A slight modification was made to Pielou's equation to allow for the estimation of the density for a hectare as unit area.

Density (D) = (n-1/n).(1/w9

where n = number of observations

w = radius squared (r^2)

r = mean nearest neighbour distance (in metres

Density for a hectare will therefore be given by D

$D = 10 \quad ((n-1/n).(1/r^2))$.

3.3 DESCRIPTION OF NESTING COLONIES

The following information on the nesting colonies was recorded: nest height, number of nests, direction of placement of nests, distance between the nearest colonies, extent of the open space associated with the colony, the distance of the colony from the edge of the woodland and the shrub density around the nesting tree.

3.4 FOOD HABITS

Food habits and preferences were determined by direct field observations of the feeding birds using a 12 by 50 wide-angle binoculars. In situations where very close observation was required, an Olympus reflex Camera mounted with a 500mm Macrozoom lens was used. Most of the observations were restricted to the times of high feeding activity. The different plants on which the birds were seen feeding were recorded. A sample of seeds from these patches was collected for reference.

3.4.1 Stomach Contents

Samples of 53 specimens of the different weavers were collected using a .410 shot gun and mistnets. Their stomach contents were later analysed. The stomachs (in the case of quelea, crops as well) were dissected out and preserved in 70% alcohol for laboratory analysis. The contents were dried and sorted out into plant and animal matter. Where possible the seeds were identified. Where identification proved impossible they were just lumped as "seeds".

Complete seeds were sorted out from the mass of the crushed ones. These were measured along the long axis. A light microscope with a calibrated ocular eye piece was used in the measuring of the seeds. A seed was placed along the scale on the slide and the length of the long axis measured.

3.4.2 Morphometric Measurements

The following morphological characters were measured: wing length, tarsus length, bill length, bill width, bill depth, tail length, hind and front claw length, length of secondaries and primaries, and the wingspan. A sample of 10 of each species was measured. Where the number of specimens for any one species was less than ten, they were supplemented by museum specimens collected from the Middle Zambezi Valley. These measurements were taken to try and find out if the morphological features had any influence on the food types taken. The ratio of the bill length between the different species was calculated, also the ratios of the bill length to the bill width and bill depth.

3.5 DATA ANALYSIS

An IBM-PC Computer was used in the analysis of data. Various statistical and multivariate computer routines were available for the purpose.

The analysis of variance (ANOVA) was used in comparing the different means of the samples to ascertain whether the differences between them were significant.

For the numerical classification of the specimens, the measurements of the characters were first standardized to +/- standard deviation units from the mean. The Euclidian distance dissimilarity coefficient was calculated for all possible pairs of individuals. Four different clustering methods were tried on the Euclidian distance matrix (WPGA, UWPGM, nearest and furthest neighbour). The Unweighted Pair Group Method (UWPGM) was found most satisfactory in bringing out the relationships between the different groups and the resultant clustering was plotted as a dendrogram (Sneath & Sokal 1973).

The correlations between the different structural habitat features of the nesting colonies of the different weaver species were analysed by multivariate techniques. As all the variables can be considered to be both dependent and independent, the Principal Component Analysis (PCA) was considered suitable. PCA was used to identify the species with almost similar nesting habitat requirements. It was also prefered because of its capacity to compress the original correlation matrix between variables and reduce the number of variables to those only with the highest covariance, without altering the original data.

CHAPTER 4

RESULTS AND ANALYSIS OF DATA

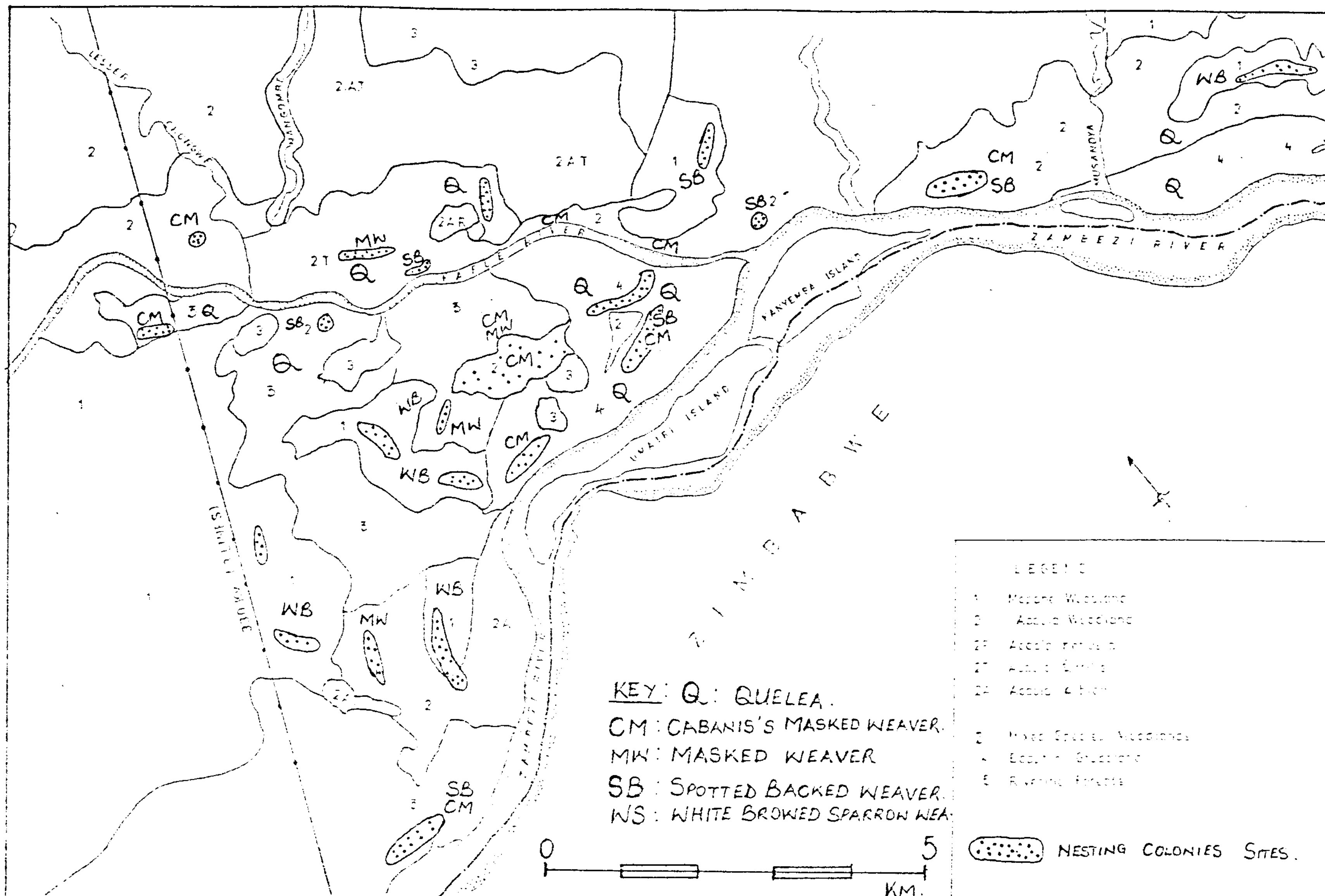
4.1 WEAVER BIRDS OF THE MIDDLE ZAMBEZI VALLEY

Twenty five (25) species of weaver birds, belonging to eight genera have been recorded in the Middle Zambezi Valley. The genus Ploceus was the most diverse with 8 species, followed by genus Vidua with 6, Euplectes with 4, Quelea with 3, Passer with 2 and the remaining genera Malimbus, Plocepasser and Petronia with one species each. Out of these, seven species were chosen as the subjects of this study viz: Cabanis's Masked Weaver, Ploceus intermedius (Ruppell 1845), African Masked Weaver, Ploceus velatus (Vieillot 1819), Spotted-Backed Weaver Ploceus cucullatus (Muller 1776), Red billed Quelea Quelea quelea (Linnaeus 1758), Red headed Quelea Quelea erythrops (Hartlaub 1848), Cardinal Quelea cardinalis (Hartlaub 1880) and the White Browed Sparrow Weaver Plocepasser mahali (Smith 1836). In the remainder of this text, the three species of Quelea are lumped together and referred to in general as Quelea. The complete list of all the weavers recorded is given in the appendix. (App. I).

4.2 HABITAT ASSESSMENT

4.2.1 Distribution of Weaver Birds

Three major habitats were identified as suitable habitats for the weaver birds in the area, basing on their occupancy, i.e.



CHIRUNDU-CHIAWA STUDY AREA: FIG: 6: DISTRIBUTION OF WEAVER BIRDS.

Mopane woodlands, Acacia woodland and the Grassland. The distribution of the three habitats is shown on the map (Fig. 6). The weaver birds are distributed over these habitats with considerable overlap as depicted in Table 1.

Table 1: Shows the distribution of the weaver birds over the habitat types in the Middle Zambezi Valley

MOPANE			ACACIA			GRASSLAND	
Pure	Mixed	Footone	Closed	Open	Ecotone	Edge	Pure
P. mahali							
			Ploceus cucullatus				
			Ploceus intermedius				
			P.velatus		Ploceus	velatus	
						Q u e l e a	

The distribution of the White browed Sparrow Weavers (<u>P. mahali</u>) is restricted to the Mopane woodland. Within the Mopane, the White browed Sparrow Weavers occupy the mixed patches which are occasionally broken by drainage lines and transition zones or ecotones. The Ploceus species, the African Masked Weaver, Cabanis's Masked Weaver, and the Spotted Backed Weavers were distributed in the Acacia woodlands. These three Ploceus species occupy areas with <u>Acacia tortilis</u> and <u>A. albida</u>, utilising regenerating areas or open woodland. The Masked Weavers extend into <u>A. robusta</u> stands and in areas of closed Acacia woodlands.

The Queleas were distributed in the Grasslands and the adjoining transitions of woodland belts. They were found in both small and large flocks. The smaller flocks were mixed with weaver birds of other species.

4.2.2 Vegetation at Nesting Sites

Apart from the White Browed Sparrow Weavers, which held more or less permanent territories, the other weavers had nesting sites away from their feeding grounds. The vegetation in the feeding grounds was slightly different from that found around the nesting sites.

The composition of the vegetation at the nesting colonies of the different weaver birds was recorded and is given in Table 2. The number of the sites at which they occured is indicated by the number in brackets. The only exception to this is in the case of the Queleas. Since no breeding grounds were found, the vegetation of the feeding grounds in which they were mainly found is described here.

Most species of weaver birds occupy more or less constant nesting habitats but the Spotted backed Weavers occupy several different nesting habitats in the area. They range from the edges of the grassland to open woodlands, regenerating fields and also villages. When in villages and in the open areas, they have very big colonies with hundreds of nests in one place. In the woodland they have smaller colonies with less than a hundred nests.

Table 2: Vegetation composition at the nesting sites of the weaver birds. The number of nesting colonies for each species is given after the species name. For the Queleas, there is no vegetation described as no nesting colonies were recorded

Weaver Species	Vegetation	
Spotted backed Weaver (14 sites)	Acacia albida(10	Digitaria spp.(4)
	A. tortilis(4)	Echinochloa spp.(4)
	Lonchocarpus capassa(2)	Eragrostis spp.(4)
	Ziziphus sp.(2)	Rottboelia spp.(4)
	Albizia anthelmintica(1)	Liliaceae(4)
	Kirkia acuminata(1)	Typha(3)
	Piliostigma thoningii(1)	Sesbania sesban(3)
	Cassia spp.(4)	Sorghastrm sp.(3)
	Solanum spp.(3)	Panicum spp.(2)
	Boscia spp.(2)	Sedges (2)
	Grewia flavescens(2)	Hibiscus(1)
	Combretum microphyllum(10)	
Cabanis's Masked Weaver (22 sites)	Acacia tortilis (17)	A.albida(5)
	Friesodielsia obovatum	Asparagus spp.(2)
	Albizia anthelmitica(4)	*Digitaria spp.(2)*
	A. robusta(2)	Solanum spp.(8)
	A. nigrescens(2)	Rottboelia sp.(5)
	Ziziphus spp.(2)	Brachiaria sp.(4)
	Lonchocarpus capassa(2)	Maerua sp. (8)
	Cassia sp.(6)	Combretum molle(4)
	Acacia ataxacantha (2)	Colo. mopane(2)
	Kirkia acuminata(2)	Grewia spp.(6)
	Strychnos sp.(1)	Commiphora spp.(2)
	Ximenia caffra(1)	C. obovata(9)
	Dichrostachys cinerea(6)	
Masked Weaver (16 sites)	Acacia tortolis(8)	A. ataxacantha(5)
	C. mopane(5)	A. albida(3)
	Commiphora spp.(6)	Grewia spp.(6)
	A. robusta (4)	Boscia spp. (6)
	Friesodielsia obovatum(2)	Cassia spp.(2)
	Tamarindus indica(2)	Solanum spp.(3)
	Kirkia acuminata(2)	Maerua(1)
	Ximenia americana(1)	Combretum spp.(9)
	Digitaria spp.(5)	Setaria spp.(4)
	Dichro. cinerea(1)	Panicum spp.(3)
White Browed Sparrow Weaver (19 sites)	Colo, mopane(16)	Digitaria spp.(10)
	Kirkia acuminata(4)	Panicum spp.(3)
	Commiphora spp.(13)	Eragrostis spp.(2)
	Ziziphua spp.(1)	Salvadora sp.(1)
	Diospyros kirkii(2)	Solanum sp.(2)
	A. robusta(5)	Commelina sp.(4)

4.2.3 Tree Preferences for Nesting Colonies

Counts of the different tree species in which the colonies were built are given in Table 3. The different weaver birds select for different tree species for building their colonies. The Masked Weavers showed no pronounced affinity to any particular tree species. 25% of their nests were in Acacia robusta, 18.7% in Ziziphus and Acacia albida. Cabanis's Masked Weaver had a bias for A. tortilis in which 74% of the colonies were established, 17.4% were in Ziziphus and the remainder in A. albida. The Spotted backed where the nest colonies were built over pools of water. In villages the nests were either in Lonchocarpus capassa or A. tortilis and Ziziphus spp.. The White-Browed Sparrow Weaver built their nests mainly in Commiphora spp. in which 64% were located. The remainder were either in Colophospermum mopane or A. robusta.

The Quelea are recorded as opportunistic in breeding habitats. They nest in scrub-Acacia woodland or in the Phragmites beds along the river banks. In this study area they have been reported to be breeding in the Phragmites beds on the islands and along the banks of the Zambezi river. A few nests were sighted during this study, but were not described.

Table 3: Number of Sites in which Particular Tree Species were used for Nesting by Different Species of Weaver Birds

Species	Nesting Tree	Number of Sites
Masked Weaver	Acacia ataxacantha	2
	Acacia tortilis	1
	Acacia robusta	4
	Ziziphus spp.	3
	Acacia albida	3
	Albizia anthelmintica	1
	Colophospermum mopane	2
Cabanis's Masked Weaver	Acacia tortilis	17
	Ziziphus sp.	4
	Acacia albida	2
Spotted Backed Weaver	Acacia albida	10
	Acacia tortilis	2
	Lonchocarpus capassa	1
	Ziziphus sp.	1
White Browed Sparrow Weaver	Colophospermum mopane	3
	Acacia robusta	3
	Commiphora spp.	13

4.2.4 Habitat Factors Influencing Bird Occupancy

14 quantitative habitat variables were recorded for each nesting colony. These were: the number of nests in the colony; height of the nests from the ground; shrub density; size of open spaces; height of the canopy; shrub and ground layers (1, H2 and H3); % cover of each of the layers for trees and shrubs; density; basal area; crown cover of the trees as well as the height of the crown. These factors were considered to be the main habitat correlates to weaver bird occupancy of a habitat.

The White Browed Sparrow Weavers were found in areas with well developed tree stands with an average tree density of 14 trees/h. The canopy trees in these areas have an average height of 10m with about 30% cover. The second and third layers were 6m and 1m tall with25% and 70% cover respectively.

Cabanis's Masked Weavers occupy areas which have a relatively high tree density with 95 trees/h. In these parts the canopy species vary from 6 to 10m tall, the middle stratum is approximately 3 to 5m tall while the ground layer is between 1 to 2m tall. The cover is generally sparse with the canopy having about 30%, the middle stratum with 20% and the ground layer with about 70% cover. The Masked Weavers occupied similar areas to the Cabanis's Masked Weavers but were found more in parts with high shrub density of 50% as compared to 30% for the Cabanis's Masked Weavers.

The Spotted Backed Weavers and the Queleas were in areas which were very open. The average tree density for the areas occupied by the Spotted Backed Weavers was about 47 trees/h. The canopy species are about 10m tall with a poorly developed middle stratum. The cover varies from 15% for the canopy to 80% for the ground cover. The Queleas occur in very open areas with a tree density of 10 trees/h. The shrub density in these areas is about 20%. In all these areas the ground cover varies greatly with season. During the dry season it can be as low as 5% and as high as 95% in the wet season.

To find out if there are similarities in the habitat factors of the 65 nesting sites and 11 feeding sites (for the Quelea only), 12 quantative environmental measurements were analysed by the

Principle Component Analysis (PCA). PCA was favoured because of its capacity to generate new axes of variation which are linear combinations of the original variables. It is also helpful in that it reduces the data matrix to only those variables that account for relatively high variation in the data and reduces emphasis on redundant ones.

Figure 7 depicts the clustering of nesting site points in the PCA hyperspace in the plane of the axes PC1 and PC2. The Quelea points form a relatively tight, isolated cluster with three obvious outliers. Close to the Quelea points and overlaping very slightly are the Spotted Backed Weaver points which form a rather loose cluster. The White Browed Sparrow Weaver points and those of the Masked Weaver form tight clusters that overlap extensively. The Cabanis's Masked Weaver points are scattered widely without any significant clustering. They overlap extensively with all the other species.

This pattern of clustering suggests that the Queleas have fairly different habitat requirements from the other species considered. The Spotted Backed Weaver happens to be close in its requirements to those of the Quelea. The overlap between the White Browed Sparrow Weavers and the Masked Weavers indicates that they may have similar habitat requirements. Cabanis's Masked Weavers may be more of generalists, utilizing a wide spectrum of sites as compared to all the other species.

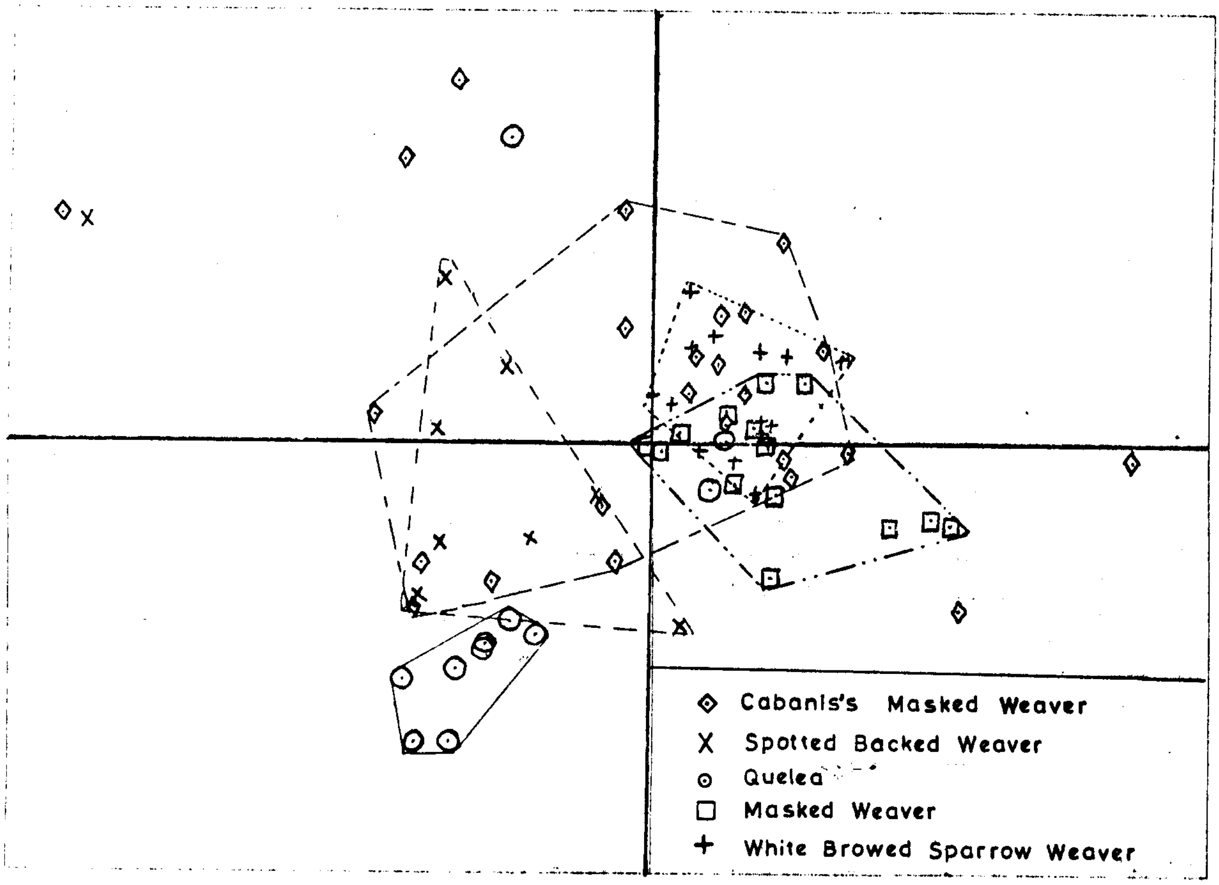


Fig 7: PROJECTION OF THE STRUCTURAL FEATURES OF NESTING COLONIES ON AXIS 1 & II (PC1 & PCII)

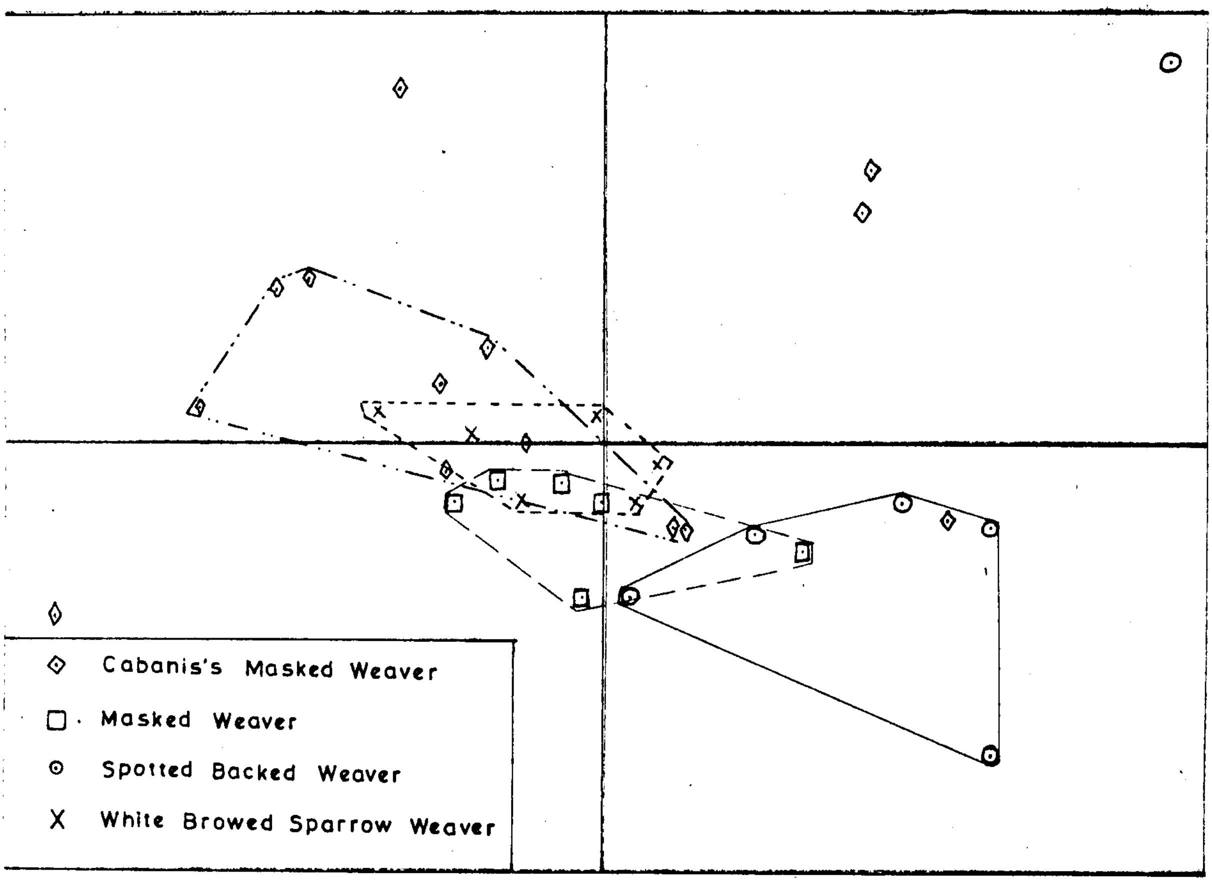


Fig 8: PLOT OF PCA LOADINGS WITH CROWN COVER AND CROWN HEIGT FOR 32 NESTING COLONIES

Focusing on the outliers on the positive and negative ends of each of the axes and examining the original data for any habitat factors which correspond with the points, it was possible to associate the first few axes with habitat factors. This process is known as "reification" of the axes. PC1 was thus found to correspond with shrub density and height of the middle stratum. The 2nd to the 4th axes, PC2, PC3 and PC4 were found to correspond with % cover of the middle stratum, height of the canopy species and the density of the tree species respectively. These four axes collectively accounted for 64% of the total variance as indicated in table 4 below.

Table 4: Percentage of the variance accounted for by the First four axes of PCA 1 and PCA 2

	PCA 1		PCA 2	
AXES	% VARIANCE	CUMM. % VAR.	%VARIANCE	CUMM. % VAR.
1	25	25	25	25
2	15	40	18	43
3	13	53	12	55
4	11	64	10	65

The extensive overlap of the White Browed Sparrow Weavers, the Masked Weavers and the Cabanis's Masked Weavers led to a reexamination of the factors used in the analysis. Two new factors, crown cover and height of the crown were considered to be important and were included in the second PCA, run without the Quelea. In this analysis only 32 of the original 65 nesting colonies, for which the new factors were measured, were used.

The Quelea were present in the grassland up to the end of the dry season. At the beginning of the rainy season no Quelea were found in the area. They reappeared in small numbers at the end of January but by March the area was teeming with Quelea, throughout the open areas. They remained flocking and wandering in the grassland from this time up till November, though in declining numbers as time passed.

4.3 FOOD HABITS

4.3.1 Field Observation

The grasses and other items on which the individual weavers were observed feeding are listed below in Table 5.

Table 5: Food items of the weaver birds as observed in the Field

Food Items	SB	MW	CM	Q	WB
Sorghum vulgere	xx			xx	
Sunflower	xxx			x	
Rottboelia exalteta	xx				
Echinochloa Column	*	x	x	xx	
Sorghastrum halepense	xx		xxx		
Panicum Spp.	x	xx		xx	
Caraspendoohachis uniflora		xx			*
Dactyloctenium giganteam			xx	xx	xxx
Digitaria Spp.		xx		xx	*
Chloris Spp.			xx		
Brachiaria deflexa			xx	xxx	xx
Flucine India			**	* *	X
Seteria Spp.			x		
Leaf & Flower buds			xx	xx	
Termites				xx	xxx
Insects		xx	xx	xxx	xx
Caterpillars	x	xx	x		xxx
Urochloa Column	*				

KEY

x - seen
xx - seen often
xxx - seen very often

Weaver Birds
* uncommonly seen

SB - Spotted Backed Weaver
MW - Masked Weaver
CM - Masked Weaver
Q - Quelea
WB - White Browed Sparrow Weaver

Table 5: Food items of the weaver birds as observed in the field

Weaver species	Food Items
Spotted backed Weaver	Sorghum vulgare, Sunflower, Rottboelia exaltata Echinochloa colonum Urochloa mossambicensis Sorghastrum halepense, Panicum spp.; Caterpillars
Masked Weaver	Panicum spp., Digitaria spp, Rottboellia exaltata, Echinochloa colonum, Caraspendorhachis uniflora, Caterpillars and Insects
Cabanis's Masked Weaver	Sorghastrum halepense Rottboellia exaltata, Urochloa mossambicensis, Panicum spp., Echinochloa colonum Leaf and Flower buds, Insects and caterpillars
Quelea spp.	Panicum spp., Digitaria spp, Dactyloctenium giganteum, Chloris spp., Brachiaria deflexa, Eleusine indica, Setaria spp.; Echinochloa colonum, Sorghastrum vulgare, Sunflower, Hodotermes mossambicus
White browed Sparrow Weaver	Digitaria spp, Brachiaria spp, Eleusine indica, Dactyloctenium spp. Panicum spp, Termites, Insects, Caterpillars.

The Ploceus species took seeds mainly from standing crops. The caterpillars and the insects were fed upon in the thickets. The Quelea fed on both the standing crop and on the ground, The White browed Sparrow Weavers fed more on the ground and in the thickets.

4.3.2 Stomach Contents Analysis

53 Specimens of weaver birds were collected in November, March and April for crop and stomach content analysis. The specimens were composed of 20 Quelea, 14 Spotted Backed Weavers, 5 Masked Weavers, 9 Cabanis's Masked Weaver and 5 White Browed Sparrow weavers.

From the analysis it was obvious that all the five species feed mainly on seeds with the exception of Cabanis's Masked Weaver which tended to have a more insectivorous diet. The Queleas fed more on small seeds, the Spotted Backed Weavers and the White browed Weavers fed mainly on large seeds but traces of small seeds were also present. The latter also fed a considerable amount of insects. The Masked Weavers fed equally on both small and large seeds.

The presence of sorghum, sunflower and bulrush millet among the crop contents show that all the weavers took cultivated as well as wild seeds. The choice of food item seems to be opportunistic. In December the weavers were dispersed in the thickets except for the White browed Sparrow Weavers which remained constantly within the Mopane woodland and the Quelea which were not seen in the area at this time.

The sizes of the seeds which were taken ranged from 1.35 to 3.90mm for the Quelea with a mean of 1.78mm. The Masked Weavers yielded seeds ranging from 1 to 4.40mm with a mean of 2.54mm. The white browed Sparrow weavers had a range of 2 to 4.4mm and a mean of 3.41mm. Lastly the Spotted backed Weaver fed on seeds ranging from 2.7 to 4.6mm with a mean of 3.64mm.

Fig 9: SIZES OF SEED FROM STOMACHS OF WEAVER BIRDS

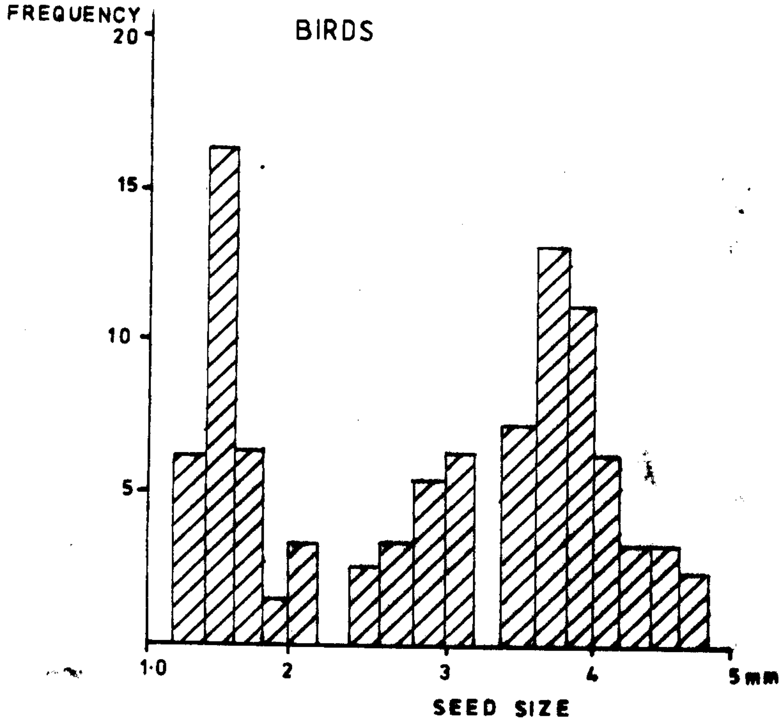
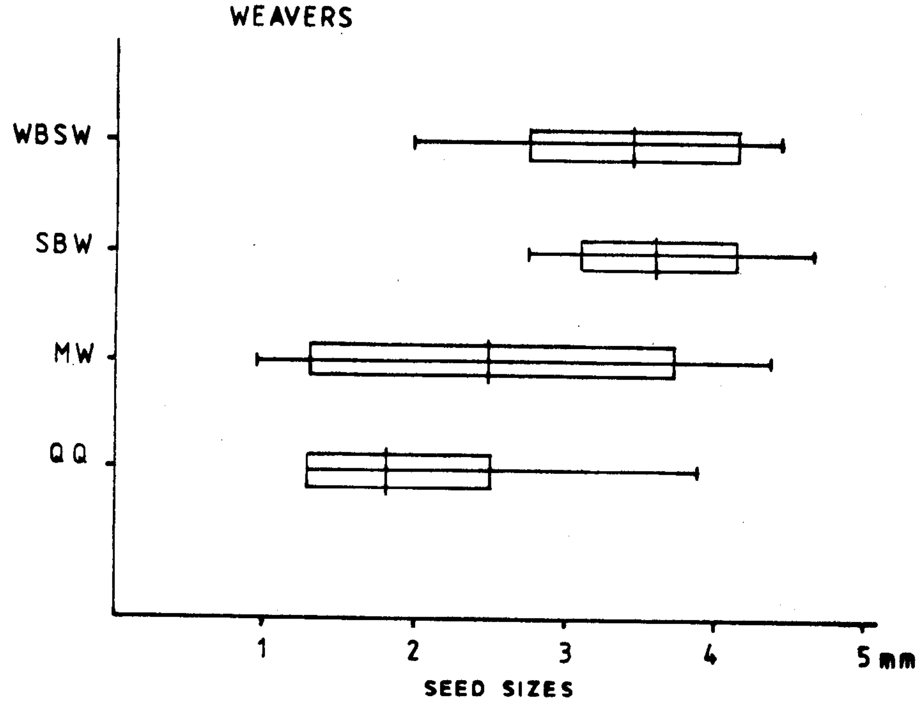


Fig 10: SIZE OVERLAP IN SEEDS TAKEN BY DIFFERENT WEAVERS



WBSW - White Browed Sparrow Weaver
SBW - Spotted Backed Weaver
MW - Masked Weaver
QQ - Quelea

The samples of seeds used were rather small as a good quantity of the extracted seeds were eaten by ants while they were being dried. The Lesser Masked Weaver samples were completely lost. The sizes of the collected seeds are shown in the bar graphs in figs. 9 and 10.

An analysis of variance was performed on the measurements of the seeds obtained from the crops and stomachs of the different birds. This showed significant variation between the sizes of the seeds taken by the Quelea and those taken by the other weaver birds. The seeds extracted from the Masked Weavers varied significantly from those found both in the Quelea and the other two larger weavers. The differences in the means are given in the Table 6.

Table 6: Differences between the means of seeds collected from the stomachs of the different weaver birds

	Quelea	M.Weaver	W.S.Weaver	S.Weaver
Quelea	*	**0.754	***1.631	***1.856
M.Weaver	0.754	*	**0.877	***1.102
WSWeaver	1.631	0.877	*	0.225
SWeaver	1.856	1.102	0.225	*

(Significance is indicated by * P< 0.05; **P< 0.01; ***P< 0.001)

4.4 MORPHOMETRIC ANALYSIS

Measurements of the 14 morphological characters indicatedin section 3.4.2 of Methods were analysed in two different ways. Firstly an analysis of variance of each of the following characters: bill length, bill width, bill depth, front toe length was calculated. These factors were considered to be the most relevant in the segregation of feeding habits and perches. The variance due to the treatments and that due to the species was found to be significant in some cases. The means of the different characters are given in Table 7.

The weaver birds differ in various dimensions of the bill. The Spotted Backed Weaver has the largest beak in all the dimensions. The bill length of the White Browed Sparrow Weavers, Cabanis's Masked Weavers and the Masked Weavers are not significantly different but their bills differ significantly in width and depth. The Queleas have the shortest beaks, which apparently are wider and deeper than that of the Cabanis's Masked Weaver. The Spotted Backed Weavers has the longest toes followed by the White Browed Sparrow Weavers. These two birds are the biggest of the weavers studied. The Queleas have fairly long toes and the Cabanis's Masked Weavers the shortest. The length of the toes give an indication of the foot span of each of the birds.

The means of the ratios of the bill length to the width and depth were calculated and are given in Table 8.

Table 7: Means of bill length, width and depth, of foot and hind toe length of the different weaver species (All measurements are in mm.)

	BILL			TOE LENGTH	
	LENGTH	WIDTH	DEPTH	FRONT	HIND
W.B.S. Weaver	14.9	6.3	7.4	20.9	16.6
C.M. Weaver	14.8	5.4	5.4	14.6	13.5
M. Weaver	14.2	7.1	7.9	17.8	16.1
S.B. Weaver	18.8	7.8	8.8	20.9	17.2
Quelea	12.5	5.9	7.6	19.5	16.0

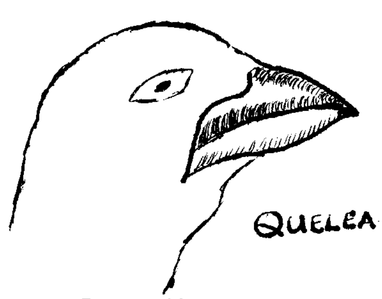
Those with the same letter are not significantly different ($P > 0.05$)

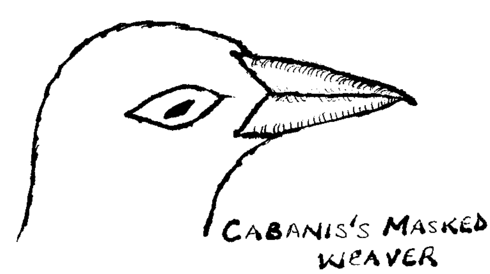
Table 8: Means of the ratio of bill length to width and depth

	Length : Width	Length : Depth
W. Browed Sparrow Weaver	2.40 b	2.ac
Cabanis's Masked Weaver	2.70	2.75
Masked Weaver	2.04 a	1.84 cb
Spotted Backed Weaver	2.44 b	2.14 a
Quelea	2.08 a	1.63 b

Those with the same letter are not significantly different ($P > 0.05$).

Looking at the ratios with reference to the picture of heads, the bills of the Weaver birds differ not only in size but in shape also. Cabanis's Masked Weavers have relatively slender beaks compared to all the other weavers which have rather stout conical beaks.





Secondly a numerical classification of the individual birds measured was carried out. Four different clustering methods were tried on a Euclidean distance matrix between the 14 morphological characters. Figure 11 is the resultant dendrogram from the Unweighted Pair Group Method.

From the dendrogram (fig. 11a), it can be seen that all of the individual birds remain within their own species clusters. The White Browed Sparrow Weavers form a very tight cluster with one outlier, while the Spotted Backed Weavers and the Masked Weavers also form tight clusters. The Queleas are formed into a chaining cluster. Cabanis's Masked Weavers separated out from all the others in a tight cluster. This shows it is relatively different from all the others.

The clustering pattern in fig. 11a gives a slightly different picture from that of the accepted phylogenetic classificatory hierarchy (Fig. 11b). The Spotted Backed Weavers and the White Browed Sparrow Weavers show a closer relationship while the Masked Weavers are associated with the Quelea leaving the Cabanis's Masked Weaver a distant relation of the group. In the accepted classification (Fig. 11b), the White Browed Sparrow Weavers are in a different subfamily to that of the Ploceus spp. and the Queleas. These two (the Ploceus spp. and the Queleas. These two (the Ploceus spp. and the Quelea) are in the same subfamily but in different genera. Since all the analyses were based on a few morphological characters its possible that body size similarity, could account for the pattern of clustering observed in dedrogram in Fig. 11a.

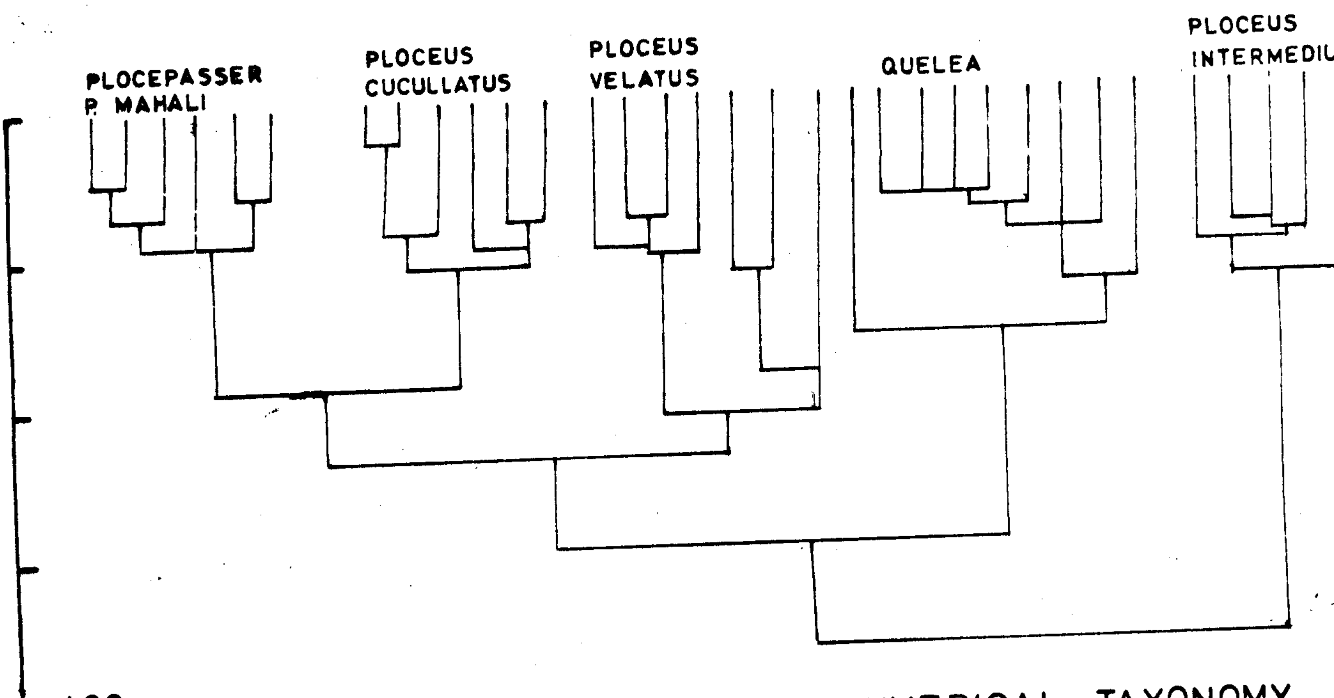


Fig 11 (a): DENDROGRAM OF NUMERICAL TAXONOMY (UNWPG ON EUCLIDEAN DISTANCE).

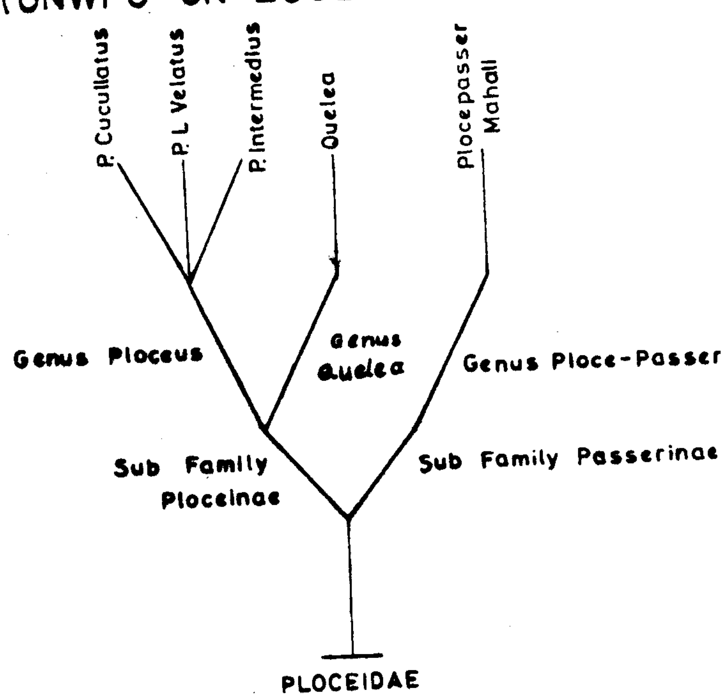


Fig 11 (b) CLADOGRAM OF ACCEPTED PHYLOGENET CLASSIFICATION.

CHAPTER 5

DISCUSSION

The observed distribution of organisms in nature led to various explanations and interpretations of the patterns displayed. One of these explanations applying to closely related species is the "competitive exclusion" principle which states that no two similar species of organisms utilizing the same resources can be *found within the same habitat at the same time (Hardin 1960).* This principle was first referred to in Darwin's writings (Mac Fadyen 1963). It was quantitatively stated by Grinell in 1904 and was popularized by the experiments of Gause (1934) who with his associates verified the theoretical mathematical models of population dynamics proposed by Lotka (1932) and Voltera (1926). Numerous studies have attested to the role of competition in the structuring of communities. Schoener (1983) and Conell (1983) reviewed 162 and 72 field experiments, respectively, and showed that more than 70% of the studies on animal communities demonstrated the effects of both inter and intraspecific competition.

Recently the competitive exclusion principle has been modified and qualified in many ways. The many examples reported of congeneric, co-existing species, mean that new explanations are needed to account for non competitive interactions. Consideration of these examples led to the formulation of the concepts of "limiting similarity" and of "differential niche overlap" (Giller 1984) which state that a degree of overlap can occur in the resource requirements of similar species and that competing species can co-exist as long as they differ in their need for one or two resources. These concepts have been supported by the patterns of habitat partitioning within assemblages of species utilizing a particular resource, or a group of resources, in a functionally similar manner. Such assemblages have been given the name "guilds". Pianka (1969 and 1973) and Schoener (1968) showed this in lizards, Hespenheide (1971) in birds and Brown and Liberman (1973) and Emmos (1980) in mammals.

The distribution of weaver birds in the Middle Zambezi Valley, seems to indicate a similar pattern within the guilds studied. The various inter- and intraspecific interactions as observed in the field will be now re-examined in order to find out which underlying factors are responsible for the structuring of the communities of weaver birds.

5.1 HABITAT PATTERNS

The seven species of weaver birds studied occupied three structurally distinct types of habitats, the Mopane woodland, Acacia woodland and the Grassland areas (fi. 6). Different preferences are obvious in different genera, leading to varying degrees of habitat isolation. The highest degree of isolation was found in the White Browed Sparrow Weavers which occupy the Mopane woodland without any other weaver bird entering the habitats in most parts of the study area. An exception to this was found in the hunting area between Malilansoro and the Chongwe River where a few colonies were recorded in a Combretum imberbe stand, a vegetation type very similar in structure to the Mopane woodland. The White Browed Sparrow Weavers inhabited those parts of the Mopane woodland in which Mopane grows in close association with other tree species like Commiphora spp. and Kirkia acuminata. They avoided well developed Moapne stands with dense undergrowth. Most of the colonies were established in ecotones or transition zones between Mopane and open drainage areas.

The three Ploceus species (the Masked Weaver, Cabanis's Masked Weaver and the Spotted Backed Weaver) were all found in the Acacia woodland along the Zambezi and Kafue Rivers. The Quelea spp. on the other hand were found mainly in the open grassland areas.

The exclusive preference of the White Browed Sparrow Weavers for the Mopane woodland habitat has so far been only noted in the Zambezi and Luangwa Valleys and the adjoining areas (Benson et al 1971 and Lewis 1982). Elsewhere in its range the White Browed Sparrow Weaver shows varied preferences of habitat, despite the presence of Mopane woodlands in some of the areas they occupy. In East Africa the White Browed Sparrow Weaver is found in dry-bush and Acacia woodlands (Williams and Arnott 1971). In South Africa, Namibia and Angola it is reported to occupy dry Acacia woodlands in which it occurs around big Acacia trees (Mac Luchlan and Riversidge 1974, Collias and Collias 1978). However, it has not been recorded whether, in these particular areas, the White Browed Sparrow Weavers co-exist with any of the Ploceus species.

The observed separation in the field could possibly be explained in that the White Browed Sparrow Weavers have similar requirements to those of the Masked Weavers, the Cabanis's Masked Weavers and the Spotted Backed Weavers to use different habitat types. As lack

(1971), Edington and Edington (1972), Hall (1960), Cody (1985) and Wiens (1985) have postulated, ecologically similar species separate in their habitat requirements or may utilize completely different habitat types especially if they are congeners. The preference for Mopane woodland by the White Browed Sparrow Weavers despite the fact that they show high affinity to Acacia scrub in other parts of Africa, presumably is an indication of avoidance of the Acacia woodland, utilized by other weaver birds. Several genera of weavers are found in the Acacia woodland and the grassland areas. Among them are the genera Ploceus, Euplectes, Passer and Petronia which are likely to have species that utilize all the items along the resource gradient of the White Browed Sparrow Weavers. This, therefore, would have meant competition had the White Browed Sparrow Weavers overlapped with the other weavers in space. It would be premature to contend that competition is the only selective pressure in this respect without direct proof or observation of the phenomenon in the field. On the other hand, it is possible that the observed separation is as a result of past competition at the time of colonisation of the area by the different species of weavers. The establishment of a colony in an Acacia woodland along a transition with Mopane, although admittedly only one observation, could be indicative of the fact that the habitat can be utilized only if unoccupied by other weavers. This phenomenon could on the other hand, be an aspect of density compensation. The White Browed Sparrow Weavers inhabit Mopane habitat because of an abnormally high density of the other weavers in the Acacia woodlands of the Middle Zambezi and the Luangwa Valleys.

To substantiate this assertion would require withdrawal experiments in which one species is removed from part of the habitat, especially along the ecotones, to see if the White Browed Sparrow Weavers would expand into the Acacia woodland. Apparently no cases of direct competition were observed in the transition zones in which the White Browed Sparrow Weavers were found in close proximity with the Ploceus spp. and the Queleas. However, Wild (1964) and Robertson (1973) reported the White Browed Sparrow Weavers are aggressive towards other granivorous and insectivorous birds at a swarming hole of termites.

Within their habitat, members of a colony of White Browed Sparrow Weavers defend all-purpose territories from individuals of other colonies (Lewis 1981, 1982, Collias and Collias 1981). Territorial behaviour is one way in which intraspecific competition is lessened in birds. By holding territories the different colonies ensure adequate availability of food resources throughout the year.

The Spotted Backed Weavers, the Masked Weavers and the Cabanis's Masked Weavers show considerable overlap in their habitat preferences, when the habitats are examined from a purely structural point of view. They occupy similar habitats in both time and space. To a certain extent they also overlap with the Quelea in their feeding grounds. If the competitive exclusion principle holds, these three species should have ways in which they separate to enable them to co-exist. At this stage a question may be posed, "To what extent do these weavers conform to the exclusion principle?" They forage in the same areas, and somtimes in mixed flocks. Their flocking behaviour, especially that of the Quelea, have been discussed at length by Ward (1965 & 1971), Ward and Zahavi (1973), Crook (1968), Zahavi (1971) and Gadgil (1972).

5.1.1. HABITAT FLEXIBILITY

The occupation of several habitat types at any one time was common in the Ploceus species. Apart from the Mopane woodlands, they were found in the Acacia woodlands and in open grassland especially in the ecotones of these two habitats (Table 1). The Spotted Backed Weaver showed the widest variation in habitat. This was most obvious in the breeding season. Its nesting colonies were found in the open grassland areas which had occasional stands of Acacia trees, in the Acacia woodlands and even in villages where big, secure trees were present. In all these habitats, the structural habitat features varied greatly. At one colony, built near a Farm House in a Ziziphus tree, the Spotted Backed Weavers returned to the colony three times in a year to breed. These three times coincide with the cropping pattern of the farm. During this time they kept their breeding plumage. Elsewhere in the study area, they moulted into ordinary plumage soon after the fledging of the nestlings in and about April.

The other two species, Cabanis's Masked Weavers and the Masked Weavers were found more in the Acacia woodlands and at the edges of the grassland areas. During the breeding season their nesting colonies were in the transition zones between Acacia woodland and the grassland areas. Most of the foraging activities were in the open areas.

Flexibility in habitat can only be explained in that the various habitats used complement one another in the type of resources that they provide to the weaver birds. The woodlands are used mainly for breeding purposes and so offer adequate nesting sites while the grasslands and the open areas have abundant grass seeds which are utilized as food. One interesting aspect that has not been reported before in Zambia is the nesting of the Spotted Backed Weavers in villages. This tendency may be a new phenomenon in the area showing either that the Spotted Backed Weavers are highly adaptable, occupying any habitat that confers maximum safety to the nests, or else that there is a dynamic situation in the population leading to overcrowding in their optimal habitats. It would be premature at this moment to say whether what was observed is typical of -distribution, in which high density is concentrated in the optimal habitats. If so, then the observed habitat flexibility can be said to be density dependent.

The three Ploceus species and the Queleas showed a marked temporal shift in habitat towards the end of the dry season just before the onset of the rains. The absence of the Queleas in the area in December suggested a possibility of nomadic movements or temporal short distance migration to some other areas which were more favourable. Ward (1973), following the patterns of movement of Quelea in West Africa, found that these movements which cause fluctuations in the numbers of Quelea were not nomadic but well ordered and regulated by the rainfall regime of the area. Johns (1985) confirmed these findings when he found that the Quelea were following the Inter-Tropical Convergence Zone (ITCZ) front within Central and Southern Africa. At this time, the Ploceus species also shift from the open grassland and the open Acacia woodlands into the thickets (Results, section 4.2.6). This could be in response to the change in environmental conditions. The area experiences extreme conditions: temperatures of above 45°C in the open and about 39°C in shade (Fig.4) coupled with a relative humidity of less than 20% were not uncommon during the study period. For a greater part of the dry hot season the climate is typical of a "semi desert". These extreme conditions may, to a large extent, influence the variations in the availability of food in the Valley, making this resource highly patchy in distribution and thus leading to the periodic shifts in habitats.

Time is one parameter that is of major importance in the Middle Zambezi Valley. The habitat is so variable over very short periods of time that the different species must time their various activities very well to make the best of the environment. The breeding activities of the weaver birds under study are concentrated within the short rainy season (about 2 months). This is necessary so that the birds can exploit the superabundant seeds and insects for the adequate development and growth of their young. A little variation in the initiation of breeding was observed. Cabanis's Masked Weaver showed the earliest nesting signs in January, followed by the Spotted Backed Weaver at the end of the same month. It was not until March that the Masked Wavers were seen building nests. The Queleas are reported to breed in January and they leave their nesting colonies just when the seeds mature. This staggering of breeding times ensures adequate partitioning of the same food resources and perhaps of breeding sites over a period of time.

5.2 NESTING SITES

For a nesting site to be selected, it should offer conditions and materials such as: nest building materials, protection from predators and abundant food resources on which to bring up the nestlings, especially if they are altricial and nidicolous. The type of predator anticipated determines the degree of concealment and the nature of placement of the nests. Most ecological studies have considered nesting sites to be limiting only in species with special requirements, such as the hole nesters and nest-holding birds like raptor birds (Cody 1974, Lack 1971 and Gates and Gysel 1978). However, in almost all species of birds, the partitioning of the nesting sites to reduce nest predation may play an important role in governing the organisation and diversity of bird assemblages (Martin 1988). The clustering, in the field (fig. 6) of the nesting colonies of the weaver birds in the Middle Zambezi Valley in particular areas, despite the widespread presence of what seemed to be suitable habitats, raises a few consideration about the likely role of the choice of the nesting sites in the distribution of the weaver birds.

The White Browed Sparrow Weavers build nests mainly in Commiphora trees within the Mopane woodland. Occasionally one or two nests in a colony may be built in a nearby Moapne tree, but this is exceptional. The colonies usually consist of 8 to 12 nests and all but one of the nests in each colony have double extrances opening downwards. The exception has one entrance and is the one used for breeding. The specific use of Commiphora trees for nesting is common only in the Middle Zambezi Valley. In the Luangwa Valley the White Browed Sparrow Weavers nest in Acacia nigrecens (Lewis 1982). This is similar to the situation obtaining in the Livingstone Area (personal observations). Elsewhere in Africa, the White Browed Sparrow Weavers use different Acacia spp. (collias 1981, Collias and Collias 1982, Crook 1964, MacLachlan and Riversidge 1971).

Cabanis's Masked Weavers show strong preference for Acacia tortilis (Table 3). In the Middle Zambezi A. tortilis has two ecological forms, the shruby, dome shaped form with branches hanging down towards the ground and the tall umbrella shaped form. Cabanis's Masked Weavers select the former dome-shaped type. The only exception to this was shown where species were nesting in mixed colonies with the Spotted Backed Weavers in which case Acacia albida was used. Unlike the other two, the Masked Weavers showed no particular preference of nesting trees. Acacia robusta, A. tortilis, Ziziphus sp. and Acacia ataxacantha were fairly evenly used as n nesting trees (Table 3). The nesting sites were set in areas where the shrub layers were very well developed. The nesting colonies were small with only 5 to 8 nests. The Spotted Backed Weavers on the other hand had a wide variation in the nesting sites. They had sites in the villages in which the tree species chosen were varied. The size of the nesting colonies in the villages had an average of 80 100 nests and in one case (at Vlahakis' Farm House) contained about 260 nests.

In all these cases the nests were built on the western side of the trees. Usually there was a considerable open space on the nesting side of the tree. The nests were suspended on fine branches stripped of leaves. The Spotted Backed Weaver colonies which were in the open areas were in young Acacia albida trees, standing in or by a pool of water. Some of these sites were well shaded while others were not. Most of the nests were in the low hanging branches just above the water. The location of nests in a tree seemed dependent on the position of both the pool of water and of the other trees.

The Quelea, unlike all the other species studied, breed in reed-beds on the banks of the Zambezi River and on some of the islands. No nesting colony was seen and described. A few nests were seen in a partially submerged reed-bed. However enquiries with the local people confirmed that the species does breed in the reed-beds.

An analysis of the structural features of these habitats around the nesting colonies by PCA gave a multidimensional comparison of the habitats. It could be inferred from the extensive overlap between the different species, as shown in Fig. 7 and 8, that the habitats of the weaver birds have many structural similarities despite the apparent differences found in the field. However they differ in several subtle factors which account for the isolation of some of the species like the White Browed Sparrow Weavers. It is along environmental factors such as crown cover, shrub density, % cover, height of the canopy, as suggested by the reification of the PCA axes, that the weavers segregate. These factors, and many others not mentioned, collectively influence the overall structure of the habitat to which the different birds respond.

In general, occupation of nesting sites seems to revolve around the provision of maximum protection to the offspring from both predators and adverse weather conditions. The placing of nests on the western side of the nesting trees helps to shelter the nests from the prevailing winds which are easterlies for the greater part of the year. The vegetative form of the nesting trees, especially in the cases of the Cabanis's Masked Weavers, the Masked Weavers and the White Browed Sparrow Weavers, is such that they do not allow easy access to the colony by a swooping predator. The Spotted Backed Weavers make their colonies almost inaccessible by building over water. This defence is crowned by the use of thorny trees. Acacia tortilis has both long stright spines and hooked thorns. Acacia albida when still young has long white spines. The form of attachment of the nests also has a predator-deterrent significance. The nests are usually suspended from fine branches which can only support weights of little more than those of the nesting birds themselves. This is most effective against climbing predators like snakes and monkeys. In some colonies many more nests are built than are used for breeding. The White Browed Sparrow Weavers build 8 to 12 nests among which only one is used for breeding purposes. It is not uncommon for the Ploceus species breeding in colonies to use a fraction of all the nests they put up. The extra nests serve to distract the predators from the functional nests (Vernon 1983, Mendelson 1968). Two incidents in which a Gymnogene (Polyboroides radiatus) was observed attacking nest colonies support this interpretation. In the first incident, at a colony of White Browed Sparrow Weavers the Gymnogene gave up the search after tearing apart four of the nests without any reward. The attack on the other colony (cabanis's Masked Weaver) was given up after the Gymnogene failed to anchor onto the fine branches, though it managed to tear apart five nests without getting any prey.

The open spaces on the nesting side of the trees serve to improve visibility around the colony. At the same time they are used as escape routes for the nesting birds in case of an attempt from predators. Studies carried out by Martin (1988) and reviewed by Ricklefs (1989), suggest that the density of predation on the nests could influence the ecological diversification of birds. To state this in another way, the avoidance of predation by nesting birds could lead to the birds occupying both optimal and sub-optimal habitats so as to reduce the level of predation.

The order of occupation of the nesting sites is determined by the peck-order system, with the heaviest and most aggressive birds in the center of the colony and the younger ones on the periphery. This could also be determined by the size of the branches on which the birds perch. The differences in foot span, as shown in Table 7, could mean that those birds with smaller foot spans like the Cabanis's Masked Weavers will keep to those parts of the colony in small branches. In most colonies it is the young non-reproductive males that build empty nests on the outskrits (Crook 1964, Collias and Collias 1978). The concentration of birds into large breeding colonies improves the visual communication of the birds. Therefore colony formation is just one of the ways in which the weaver birds enhance their protection against predators (Ward 1966).

Though Orians and Willson (1964) correlated the choice of nesting sites to the spatial and temporal distribution of food resources for species with altricial young, avoidance of predators could be of more importance. The whole pattern of the dispersion of the nesting colonies in the area points to systematic partitioning of the predator escape space.

5.3 FEEDING HABITS

It is widely accepted that numbers of individuals of a species are ultimately limited by food abundance (Crook 1964) and that related species that co-exist within the same habitat segregate on the resource level: e.g. food (Hardin 1960). If this be true then the principal factor determining the survival of individuals of a species are those adaptations concerned with the utilization of the food resources available to them.

The weaver birds under study are primarily granivorous (Rowan 1971 and Skead 1964). From field observations, they feed indiscriminately on the seeds of the grasses within their habitats. The

Spotted Backed Weavers, Cabanis's Masked Weavers, the Masked Weavers and the Quelea were all foraging in the open grassland in flocks of different sizes. Two different patterns of flocking were evident. Large flcoks of Quelea were mainly composed of a single genus, while the smaller flocks were mixed.

The flocks were rather restless, hardly spending more than 30 minutes on any one single feeding patch. According to Ward (1965), Ward and Zahavi (1971), Zahavi (1971), Gadgil (1972) and Gichuki (1985), the Quelea flocks and those of the Ploceus species act as:

i. communication centers for the monitoring of food over a large area.

ii. a means of preventing overlap in foraging areas used by the different weaver flocks.

Following from these, flcoking has a survival advantage in the granivorous weaver birds. It helps to expand the area across which food is searched for by the various individuals in the flock. The joint use of the food resource possibly reduces competition with other congeneric species. In this regard flocking increases the possibility of niche overlap in that the different species can be foraging on different items in the same feeding ground at the same time. The changes in the flcoking patterns, from large flocks in the rainy season to small mixed ones at the height of the dry season may be due to the drop in the different types of food items utilised and also to reduction in the wide overlap patterns. One consequences of this to the birds is that diets can change, apparently opportunistically, as different food types become available.

Despite the observed overlap in the feeding habits, a few differences were observed. Cabanis's Masked Weavers fed more on flower buds, leaf buds and insects. The Masked Weavers tended to utilize fruits, buds and insects as well. The Quelea remained granivorous throughout the time they were observed.

The White Browed Sparrow Weavers used both seeds and insects as food items. As stated earlier their feeding activities are confined to all-purpose territories. An attempt to determine the size of the occupied territories by successive flushing of the birds led to a rough estimate of an area of about 250 meters radius per family unit.

It was difficult to find out exactly what determines the choice of food items. The only possible explanations is the presence and abundance of the particular food resource utilized in the area at the time. In most cases when flocks appeared to avoid certain patches, the grass growing there had not yet seeded or the seeds were not yet mature. From field observation it was not possible to tell exactly what each weaver species took, hence they can be described opportunistic. Several authors working on weaver birds have concluded to this fact (De Camara Smeets 1985, Crook 1964 and Collias 1974).

5.3.1 DIETARY OVERLAP

Although the field observations show complete overlap in diet by the three Ploceus species and the Queleas, a limited examination of the stomach contents showed that the different weaver birds do in fact take different types of seeds from their feeding habitats.

This may be likened to the case White (1951) reported of separation in the type of food taken by breeding Cabanis's Masked Weavers and Spotted Backed Weavers on the shores of Lake Mweru.

As the seeds were difficult to identify to species, they were differentiated according to size. Measurements of the long axis of the seeds extracted from the stomachs grouped into three categories as shown in Results fig. 9. From the various seed size ranges it is obvious that there is more overlap in the utilization of seeds in the small size range than in the large size range (fig. 10). What is more significant is that the birds do separate along a food gradient though this can be masked by the abundance of the particular seeds in the area at a particular time. These findings, however, only show that at the time of collection of the specimens, the seeds obtained were those more readily available to the different species. Experimental studies by Erickson (1985) and De Camara (1981, 1987), on the other hand, have shown that the granivorous weavers show marked preferences in food types when the different types of seeds are abundant. When the seeds become scarce, they turn to the seeds of sizes which were earlier avoided. These shifts in food habits are most clearly manifested in the pest activities of the weavers on small seed crops (Chapter 6).

The differences in the sizes of the seeds taken by the different species may be suggestive of some level of separation along a resource gradient but, only to a limited extent. The similarity in bill morphology of the weavers suggest the same resources (Travis and Ricklefs, 1983, Ricklefs, 1977 and Schoener, 1965). The measurements of the bill showed that there are considerable differences in the sizes both in the same species, (by way of sexual dimorphism) and also between the different species. The means of the bill measurements (Table 7) show that the weaver birds differ significantly in different dimensions of their bills. The ratios in Table 8 show further that the differences are not only in size but in shape as well. These variations in bill size and shape point to different dietary specialisations. Assuming that the short-stout beak with the upper and lower mandibles of equal length is typical of granivorous birds, then the Queleas, Masked Weavers and the Spotted Backed Weavers could be more or less obligate granivores. The White Browed Sparrow Weavers would feed equally on both insects and seeds and the Cabanis's Masked Weavers would be inclined to being insectivorous. The ratios of the bill length between the different weaver species range from 1.2 to 1.5, which, according to Hutchinson's rule (Hutchinson 1959), give a limit of similarity for competing species (Giller 1984). In other words, the different weaver species are similar enough to compete despite their co-existing within their habitat.

These differences in morphological characters, in general, indicate the prevalence of differential niche overlap (Smartt 1978). The closeness in morphology and the great extent to which seeds are exploited indiscriminately imply one of the following:

i. several resources are important to the weaver birds and this offsets the possible competition.

ii. Foof as a resource is not limiting, especially during the season when the greatest overlap is observed in the field.

or iii. the community is not saturated and so there is a chance of other individuals joining it.

What may interfere with the predictions of Hutchinson's rule is the option of refuges among the weaver species in times of stress. The niches of the different weaver birds are not fixed. They are small when conditions are favourable and food is superabundant and are widened when resources are scarce. The expansion of the niche dimensions entails turning to the different alternatives which would have been otherwise avoided under favourable conditions. The variations in these different foods taken in times of stress show that it is in the choice of these that the weavers seem to have selected for more pronounced isolation. These temporal specific reserves for each of the species, it would seem, ensure that the different species can co-exist and exploit the same food resources when it is superabundant, but isolate out when resources are in such short supply as to result in competition. The presence of these temporary niche dimensions, as observed, allow for more latitude in the use of the habitat by different species which could otherwise have been serious competitors. This may explain the presence of so many weaver bird species in the study area.

5.3.2 SEASONAL VARIATION IN DIET

The level of food resources in any given habitat varies with time. When the environmental conditions are favourable, food is usually abundant and it becomes scarce as the environment becomes harsh. Different modes of dispersion are adopted by different animals to cope with such environmental fluctuations. The Middle Zambezi Valley, as stated earlier, experiences severe seasonal variations. These extreme conditions mean that animals and plants need to have ways of surviving this stress period.

As a direct response to these fluctuations in the environment, the different weavers change their dispersion patterns. The Queleas migrate to the East Coast (Jones 1985, Ward 1971). As the dry season progresses, seed stocks are depleted and new readily available stocks need to be found. The South East of Africa receives rain earlier than the central parts and so seeds are produced earlier there. The Quelea migrate presumably in order to take advantage of these. The Ploceus species extend their niche dimensions by turning to the small seeds and also by taking in a relatively large spectrum of food items (Ward and Zahavi 1973, De Camara Smeets 1981, 1987).

5.4 SUMMARY AND CONCLUSIONS

The question of habitat selection revolves around the patterns of resource partitioning by a given guild. These patterns are adaptations of the diferent species to different levels of co-existance in any given habitat. From the foregoing, it is evident that certain adaptational mechanisms have been at play in the weaver bird community of the Middle Zambezi Valley to bring about the observed distribution and dispersion in the field.

1. Weaver birds show different degrees of habitat isolation. They vary from complete spatial separation to differential niche overlap. The White Browed Sparrow Weavers show complete separation from the other species in space. This could be due to avoidance of possible competition or due to past competition, commonly referred to as the "Ghost of Competition" (Townsend et al. 1984). The Ploceus species show different patterns of segregation. During the breeding season they occupy relatively different habitats for nesting but maintain similar feeding grounds. The dispersion patterns of the Ploceus species and the way in which they utilize the different resources could be taken as an example of differential niche overlap.

2. Most of the weaver birds seem to be opportunistic feeders, taking whatever grass seeds that are available in the area that they are in at any particular time. The abundance of food resources seem to determine the pattern and nature of exploitation. During times of abundance, the weaver birds segregate on the type of seeds taken, while maintaining both large and small flocks. As food stocks get depleted, they tend to be more indiscriminate in their food intake and the flocks become smaller. Different strategies are adopted to cope with the harsh conditions. The

Quelea move out of the area into better ones. The *Ploceus* species turn to different food reserves such as insects, leaf and flower buds and the like.

3. The selection for predator free space for nesting sites seems to influence the distribution of the weaver birds during the breeding season. They breed at a time, where most of the grasses in the area are maturing. Seeds and insects are plentiful. The avoidence of some places in preference for others is indicative of another driving force than the distribution and availability of food, namely, avoidance of predators. The tendency observed in the Spotted Backed Weavers to breed in villages is an example of this, as villages offer relatively adequate protection against predators. This tendency may have other implications as well. It could be as a result of interspecific competition for nesting grounds or it may signify an over dispersion in the spatial distribution of the Spotted Backed Weavers. Confirmation of this would need more research in the population dynamics of the various weaver species.

4. Finally it can be said that the selection for the different habitats by weaver birds hinges on the three complementary selection pressures arising from habitat structure, food availability and presence of nesting sites.

Habitat structure is primary to all these in that it dictates the amount of food available and the presence of suitable nesting sites. Habitat factors such as crown cover, shrub density, % cover, height of the canopy, seem to be some of the primary cues used in selection. The presence of good nesting sites will determine the dispersion of the weaver birds during the breeding season, as these are occupied first. New colonies are only started when old ones are saturated, thus necessitating over-dispersion. The availability of food resources determines the dispersion of the various weavers within the area.

The various adaptational mechanisms obvious in the weaver birds have made it possible for the many similar species to occupy a limited and variable habitat without observable cases of competition. Habitat segregation, differential niche overlap, variable niche dimensions, dietary variations and the separation of breeding activities in time, are all mechanisms used to maximise aspects of resource partitioning and habitat utilization. This is enhanced by the various morphological adaptations and differences among the weavers. The variation in the size of the bill, feet or claws and the wing, mean that birds can feed on different foods, perch on different sizes of branches and cover different size areas.

At the end of all this the question of habitat selection among the weavers still remain an open one. It can be said however, that habitat selection and competitive segregation should be regarded only as proximate causes of habitat partitioning. The ultimate significance of all these processes lies in the subdivision of food resources and nesting sites between the different species of weaver birds.

CHAPTER 6

WEAVER BIRDS AND LAND-USE IN THE MIDDLE ZAMBEZI VALLEY

A PRELIMINARY ASSESSMENT

Weaver birds are infamous for their role as agricultural pests in many parts of Africa and Asia. Records of Quealea, especially, as pests go as far back as 1881, when they were reported to have been a contributory factor in bringing famine to Central Tanzania (Elliot 1985). In Southern Africa Quelea cause a problem of considerable magnitude to farmers particularly in areas where they breed in large colonies (Naude 1959). According to Ward (1965), Quelea are birds of fertile alluvial soils subjected to seasonal flooding where the grasses which provide their preferred seeds grow in great profusion. The problem of their pest effects therefore is aggravated by the fact that their distribution in most cases coincides with agriculturally suitable areas. The problem of birds as pests is sufficiently acute, at least in some regions, to merit the convening of four International Conference (as indicated in the introduction), to review their status as pests in relation to their ecology and management.

Zambia has not yet seen a major Quelea outbreak on a wide scale. Local incidences do, however, occur in isolated parts of the country where their numbers are high. Three species of Quelea, the Red-billed Quelea, the Red-headed and the Cardinal Quelea are recorded in the country where they are found in open woodland areas and areas of rank grass (Benson et al 1971). The Red-billed quelea has a wider distribution than the other two species. Despite their wide distribution they are reported to breed only in the Middle Zambezi and the Luangwa Valleys. Considerable numbers of large flcoks of

Quelea in company with other weavers are a common sight in the area. To appreciate the implications of the ecology of the weavers on the land use pattern in the area, a knowledge of the land qualities and capabilities is necessary.

6.1 LAND EVALUATION OF THE MIDDLE ZAMBEZI VALLEY

Trapnell (1953) divided Zambia into three ecological zones on the basis of the amount of rainfall received in the different areas. With the North-South decrease in annual rainfall, the Southern part which receives less than 800mm was designated as zone 1, the middle zone with rainfall between 800-1000mm as zone 2, and those areas in the Northern part with more than 1000mm of rainfall as sonze 3. Veldkamp (1985), with the Mount Makulu Soil Survey Unit sub divided these zones into subzones based on the agricultural potential of each. These subdivisions are called agro-ecological zones. The Middle Zambezi Valley, is classified as zone le which according to this evaluation has the following land qualities:

1. Relatively fertile soils suitable ror crop production in some parts.
2. Uneven topography and shallow soils on the rock outcrops.
3. Short rain season from December to early March. This provides for a short growing season of 80-100 days as compared to the other zones with an average growing season of 135-147 days.
4. The area receives moderate rainfall below 800mm with a 70% probability. It also experiences an approximate drought period of 30-50 days during the growing season.

5. Temperatures vary from hot to very hot but rarely are any frosts experienced at all.

The major land limitations of the area are low moisture availability and uneven topography. From this information it is obvious that rain-fed agriculture is subject to major risks. These major limitations have restricted the choice of crops to drought resistant and early maturing crops such as Sorghum (Sorgustrum vulgare), and other small seed cereals, which happen to be vulnerable to birds. The other limitations (uneven terrain) has restricted agricultural activities to alluvial beds and small openings in the woodlands where the land is relatively flat. Big agricultural schemes therefore, require major land improvements such as levelling and irrigation.

6.2 LAND USE

For a long time the major land use, on a commercial scale, in the Chiawa part of the Middle Zambezi has been designated as Wildlife and Tourism. This designation has been due to high infestation levels of Tsetse fly and the unpredictable and inadequate rainfall (Chabwera 1985).

On a subsistence level the main land use is semi-permanent agriculture with hoe and axe. The basic land use system is the growing of several drought resistant crops as shown in the table.

Table 9: Land use systems in subsistence agriculture

Type of use	Varieties
Cereals	Bulrush millet (Pennisetum typhoides)
	Sorghum (Sogastrum vulgare)
	Maize (Zea mays)
	Finger millet (Eleusine caraca)
Cucurbits	Pumpkins (Cucurbita spp.)
	Water melon (Citrullus vulgaris)
	Cucumbers (Cucumis spp.)
	Gourds (Logenaria vulgaris)
Vegetables	Okra (Hibiscus esculentus)
	Sesame (Sesame orientalis)
	*Sishungwa (Gynandropsis gynandra)
Fruits	Pawpaws (Carica papaya)
	Bananas (Musa sapientum)
	(M. cavindish)

(* Vernacular name)

Recently a few cash crops have been introduced in the area. Cotton is encouraged on a wide scale. Bananas have been popularized by the two banana schemes in the area. To a lesser extent Sunflower is also being tried in a few places.

Two types of fields are cultivated. Those on the river banks and leves are known as Matolo. These are used mainly for the growing of maize. Being a less drought resistant crop it benefits from the soil moisture left by the receeding floods. Two crops of maize are grown in the same field in a year. The first from November to March and the second from April to July. Since the impoundment of water at the Kariba and Iteshi-teshi Dams, the extent of the floods down stream on the Zambezi and Kafue Rivers has been reduced. This has led to the failure of many a second crop. Sorghum, millet and cotton are grown in fields which are further from the river and are known as Minda (Munda singular). These are usually cleared gardens in the woodlands. Two of the islands on the Zambezi, Umairi and Kanyemba are intensively utilized for maize growing.

6.3 EFFECTS OF AGRICULTURE ON WEAVER BIRDS

From field observations made during this study, it was evident that the distribution of the weavers, with the exception of the White Browed Sparrow Weaver, id directly favoured by farming. Of the 96 observed nesting colonies, 78.4% were found in places which were in one way or another modified by farming.

Among the seven species of weavers considered, the Red billed Quelea were the most numerous in the open areas. These were mainly abandoned fields, grasslands on the flood plain and the clearings near cultivated fields. Small to medium size flocks were evident throughout the area, near cultivation and in the fields themselves.

6.4 PEST ACTIVITIES OF WEAVERS

Naude (1959), estimated the loss of grain crops due to the activities of the weavers, the quelea especially, at about 4,000 to 5,000 bags of crops in an estimated produce of about 50,000 bags. In a much later review Elliot (1985) puts the total loss of agricultural produce attributed to weaver birds for any one nation at about 5% or less of Gross National Product. On a continental basis this would be about 1%. These figures are insignificanct when considered on a broad national or continental scale. But as weavers have localized distributions, their effects are in most cases localized. In this case the damage caused to crops or the loss incured may be significant enough to cause concern (Gichuki 1984).

Weavers have a high concentration in the Middle Zambezi Valley. Large flocks of mixed species are often a common sight. These are capable of going through a small field of a crop in a short period of time. Reports from local people confirm that considerable damage is inflicted on the crops by the weaver birds. The magnitude of this is yet to be established. Scudder (1960, 1971) working on the land use systems of the Gwembe Tonga pointed out the weaver birds as one of the major pests of the crop in the field. Sorghum and bulrush millet suffer the most as they are taken as standing crop (Erickson, 1985).

Other crops such as maize sufer little from the weaver birds. Apart from the Spotted Backed Weaver which was found attacking maize while the kernels were still white and milky at one of the local farms (Vlahakis' Farm) none of the other weavers was considered a problem. Usually in these incidents the husks are pulled off and the cobs are picked clean.

Experimental investigations have shown that Queleas have a daily intake of about 2.5g of seeds and the Spotted Backed Weaver takes about 8.3g (De Camara Smeets 1981; 1987; De Camara-Smeets and Manikowski 1981). On a monthly basis each quelea will take about 75g and the Spotted Backed Weaver about 250g. Taking these values into consideration along with the large numbers of the birds, it is obvious that serious damage can be caused when flocks invade fields.

This aspect of the ecology of the weaver birds has a significant influence on the pattern of life of the people of the Middle Zambezi Valley. At the time when the cereal crops are coming into season, families shift from villages into make-shift huts in their fields. This is to allow them to be present in the fields most of the time to chase away the birds and other pests. They do this by shouting and beating tins. To make their efforts more effective, they tie long bark fibrecords to the stalks across fields, knotted to others running in all directions, so that a jerk by a single watcher agitates the plants over a wide area and frightens off the birds. This activity starts around 5.30 hours in the morning and ends about 18.30 hours. At peak feeding hours, choruses of shouts and noises can be heard all over the valley. This means that very little other work can be done during this time. As most of this is considered women's duties, mothers can hardly engage in any profitable ventures for the length of the time the crop is maturing in the field.

6.5 CHANGING PATTERNS OF LAND USE

To date most of agriculture in the valley was of the "low level input" type. Without major land improvements, the outstanding limitations of drought and topography meant that only small areas could be cultivated. These form patchy pockets over a wide area but nothing large enough to cause a major shift in the environment. Currently big new agricultural schemes with high level and intensity inputs are being developed in the area. These call for clearing vast expanses of the natural vegetation and the establishment of irrigation facilities. An example of this is the Masstock Chiawa Agricultural Scheme, in the Chiawa farming block, which is being developed in five phases. At the completion of these, 186,000Ha of land would be under cotton and wheat.

Although many natural habitats will be destroyed, a uniform open grassland will be created. This will enhance the growth of grasses such as Echinochloa, Wild Sorghum, Panicum, Tetrapogon and Setaria. Erickson (1985) found that in some arid zones, the diets of the quelea especially were mainly confined to mainly small wild grass seeds, particularly Echinochloa. This particular gems is a major weed of irrigated schemes. Pending further investigation, it seems legitimate at this stage to predict that the abundance of grass in the cultivated and irrigated cotton and wheat fields will favour the growth of the population of the weavers.

In view of these recent developments in the Middle Zambezi Valley, the following recommendations may be made:

1. A monitoring station, should be set up to study the dynamics of the populations of weavers and other granivorous birds which are potential pests.

2. Monitoring should include the full recording of data and the acurate mapping of all the weaver concentrations found in the area.

3. Systematic and regular assessment of birds damage levels and cereal crop production, should be made. This would form the basis for the evaluation of the effectiveness of any control operations.

APPENDIX 1

Check list of weaver birds recorded in the Middle Zambezi Valley

Abbreviations: Status St; vc- very common; c- common; uc- uncommon; r- rare

Date Refers to month of year.

SPECIES NAME	COMMON NAME	DATE	LOC	ST.
Ploceus xanthops	Large Golden Weaver	11,12,2	ZTF	c
P. intermedius	Cabanis's Masked Weaver	7,8,11	St.A.	vc
	Lesser Masked Weaver	1-4		
P. velatus	African Masked Weaver	11,3,4	ZTF	uc
	Masked Weaver			
P.cucullatus	Spotted Backed Weaver	11,12,	St.A.	vc
	Village Weaver	1-5		
P. bicolor	Dark-backed Weaver	4,5	Chir.	r
P. ocularis	Spectacled Weaver			
Malimbus rubriceps	Red-headed Weaver	9-12,3-4	Chir.	c
Quelea cardinalis	Cardinal Quelea			r
Quelea Quelea	Red-billed Quelea	01-11	St.A	c
Quealea erythrops	Red-billed Quelea			r
Euplectes orix	Red-bishop	01-06	St.A.	c
E, capensis	Yellow-rumped Whydah	2-4	St.A.	c
E. hordaceus	Black winged Bishop	1-3 10,11	ZTF	c
E. albonotatus	White-winged Whydah	1-4	ZTF	c
Plocepasser mahali	White-browed Sparrow W.	1-12	St.A.	vc
Passer domesticus	House Sparrow	2-4	St.A.	c
P. griseus	Grey headed Sparrow	11,12 01	Chia	c
Petronia supercil-liaris	Yellow throated Sp.	11-04	Chia	uc
Vidua macroura	Pin-tailed Whydah	01-04	St.A.	c
V. purpurascens	Pink-backed Firefinch	3-5	St.A.	c
	Purple widow finch			
V. funerea	Brown backed Firefinch	1-4	St. A.	c
V. chalybeata	Red billed Firefinch	11,12	Chia	c
V. paradisea	Long tailed Paradise Widow	1-4	St.A.	c
V. orientalis	Broad tailed Paradise Widow	1-4	St.A.	c
Ploceus xanthopterus	Small Golden Weaver	1-3	ZTF	r*
P. olivaceus	Olive-throated Weaver	1-3	Chia	r*

* Refer to unconfirmed records.

APPENDIX 2:

Table 10: Quantitative environmental factors associated with nesting sites of Weaver Birds

NH	NN	SD	OS	HH1	H2	H3	CL1	CL2	CL3	DEN	MCBH	CRA	CR
Cabanis's Masked Weaver:													
3	0	90	3	20	10	2	50	20	80	34	105	0	[illegible]
2	12	30	10	10	6	1	5	30	70	64	33	17	[illegible]
4	20	10	500	10	5	1	10	20	85	94	49	14	[illegible]
0	0	30	20	10	6	2	60	30	60	330	87	0	[illegible]
3	160	0	0	8	3	0	30	20	0	10	47	27	[illegible]
4	16	70	200	10	4	2	5	50	60	53	51	34	[illegible]
0	0	50	50	10	3	1	70	60	70	70	78	0	[illegible]
0	0	0	40	8	2	1	40	50	70	50	42	0	[illegible]
4	6	40	40	15	5	1	20	70	10	290	95	25	[illegible]
2	3	30	70	6	3	1	40	30	70	57	46	21	[illegible]
0	0	30	500	8	2	1	10	20	70	32	53	0	[illegible]
0	0	30	5	12	6	1	80	40	30	120	50	0	[illegible]
4	3	60	20	6	2	1	10	40	60	49	40	21	[illegible]
3	3	80	30	8	5	1	30	40	70	101	47	25	[illegible]
4	2	0	10	8	6	1	30	20	70	49	42	17	[illegible]
15	7	0	10	25	15	3	40	50	70	160	141	27	[illegible]
4	2	60	30	15	6	1	60	30	90	17	130	18	[illegible]
4	3	30	30	60	4	1	60	10	20	103	47	33	[illegible]
3	2	60	0	4	2	1	30	10	70	330	97	0	[illegible]
4	3	0	40	8	1	0	10	60	0	32	46	61	[illegible]
4	2	0	40	5	3	1	40	20	70	273	32	0	[illegible]
4	2	40	10	15	8	1	10	15	50	12	47	0	[illegible]
3	200	0	300	15	1	0	5	70	0	3	149	0	[illegible]
2	150	5	400	15	2	1	5	10	70	22	79	0	[illegible]
4	8	40	10	12	6	1	10	13	9	83	29	0	[illegible]
2	180	5	500	15	2	1	5	10	85	75	85	61	[illegible]
3	300	0	200	15	2	1	5	10	40	43	73	0	[illegible]
Masked Weaver:													
3	23	5	100	12	8	1	5	30	60	9	66	95	[illegible]
2	2	70	3	20	8	2	10	15	50	283	40	0	[illegible]
3	5	60	3	15	8	2	5	15	70	184	0	0	[illegible]
4	8	5	50	15	6	2	10	5	70	141	68	0	[illegible]
8	5	30	10	12	3	1	5	30	80	68	72	0	[illegible]
3	4	70	40	15	6	2	10	30	70	19	67	0	[illegible]
4	2	60	30	5	3	1	50	10	60	153	28	35	[illegible]
3	5	50	10	15	6	1	10	30	70	86	65	0	[illegible]
8	2	40	50	10	4	1	15	10	50	10	110	0	[illegible]
4	5	30	5	15	6	1	10	30	60	83	33	78	[illegible]
4	4	30	7	8	4	1	10	30	80	11	39	35	[illegible]
4	8	50	4	8	4	1	10	5	70	33	46	0	[illegible]
2	6	10	50	12	8	1	30	10	80	83	61	71	[illegible]
3	8	30	5	15	6	1	10	20	60	13	47	7	[illegible]

Quealea spp.

0	0	20	500	15	4	1	15	10	90	5	160	0	0.0
0	0	10	500	15	3	1	10	10	90	6	164	0	0.0
0	0	20	200	10	4	1	10	20	90	5	156	0	0.0
0	0	10	200	10	2	1	15	10	90	2	171	0	0.0
0	0	60	0	8	2	1	30	20	70	8	66	0	0.0
0	0	20	300	15	3	1	15	10	70	8	164	0	0.0
0	0	40	500	10	2	1	10	15	70	17	157	0	0.0
0	0	5	30	8	2	0	30	40	0	1	66	0	0.0
0	0	20	30	15	3	1	15	10	90	6	164	0	0.0
0	0	10	400	20	3	1	5	10	85	4	1	0	0.0
0	0	30	50	20	6	1	5	30	80	22	33	0	0.0

Spotted Backed Weaver:

4	1	40	30	8	5	1	60	10	70	63	34	93	9.0
3	35	5	500	8	4	2	10	15	80	38	46	129	12.8
3	41	31	500	6	4	1	20	30	70	146	47	56	8.0
4	120	30	500	8	2	1	10	30	80	10	74	61	5.2
3	200	5	300	15	2	0	5	70	0	10	149	95	10.1
2	180	5	500	15	2	1	5	10	80	75	85	70	7.5
3	200	0	200	15	2	1	5	10	40	43	73	0	0.0
3	30	30	200	8	2	1	10	20	1	32	53	0	0.0
3	160	0	200	8	3	1	30	25	7	10	47	0	0.0

White Browed Sparrow Weaver:

3	10	5	5	10	5	1	60	30	70	400	71	51	7.8
3	12	10	7	12	6	1	60	40	80	295	74	22	5.5
3	10	0	5	8	3	1	50	30	70	74	54	75	6.5
3	11	0	5	8	3	1	70	30	50	62	68	70	5.2
8	10	10	5	15	10	1	40	30	60	85	107	0	0.0
3	14	10	20	8	4	1	50	30	60	85	52	0	0.0
4	10	20	10	10	6	1	50	10	70	155	93	71	5.3
4	10	10	10	8	5	1	20	15	70	69	87	0	0.0
3	9	10	20	15	8	1	20	15	55	44	47	61	8.6
3	6	5	10	10	4	1	10	15	60	26	52	0	0.0
4	10	10	10	10	6	1	20	5	60	520	53	0	0.0
4	8	5	40	15	8	1	20	10	80	183	55	0	0.
4	5	5	20	10	4	1	10	30	70	44	58	0	0.0
4	8	5	50	6	3	1	10	30	70	87	53	0	0.0
4	12	5	30	15	6	1	20	10	70	73	63	0	0.0

Key to headings:

NH - Nest height
SD - Shrub density
HH1 - Height of canopy
H3 - Height of layer 3
CL2 - % Cover layer 2
CRA - Crown area
MCBH - Mean circum, breast height

NN - Number of nests
OS - Open Space
H2 - Height of layer 2
CL1 - % Cover layer 1
CL3 - % Cover layer 3
CRHT - Crown height
DEN - Density

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