THE ECOLOGY OF THE RED-BILLED QUELEA *QUELEA QUELEA* (LINNAEUS) AND OTHER GRANIVOROUS BIRDS AT EASTERN CAPE FEEDLOTS

A thesis submitted in fulfilment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

of

RHODES UNIVERSITY

by

CRAIG ALUN WHITTINGTON-JONES

November 2001

ABSTRACT

Red-billed Quelea *Quelea quelea* have expanded their range in the Eastern Cape and now occur throughout the year in new areas. Recent changes in agricultural practice have probably been a contributing factor as flocks are larger than previously recorded and were more often associated with artificial food sources than natural grasses.

Ringing and census data indicate that quelea have reduced movements during the non-breeding season and may display strong fidelity (over successive years) to dry season quarters with reliable food supplies. Although the recapture/recovery rate for quelea in the Eastern Cape (1.0-2.5%) was higher than the national average, it was still lower than expected and there may be considerable movement between nearby feeding sites.

Some quelea breed locally, but most disperse during summer and their numbers at the feedlots were generally highest in winter and spring. The breeding season of quelea is later than other ploceids in the region and post-nuptial moult overlaps with winter. Replacement of primary wing feathers is relatively slow (124 days), and this is considered an adaptation to minimise disruption of flight capabilities and insulation.

Significantly more quelea in the Eastern Cape have breeding plumage suffused with pink than in other southern African populations. However, during the non-breeding season there is apparently considerable intermixing between local populations and those from further north and the existence of a local sub-species is not supported.

Seeds of two grass species, *Echinochloa* sp. and *Urochloa panicoides,* and two weed species, *Amaranthus* sp. and *Chenopodium* sp., were important in the diet of both quelea and Laughing Doves *Streptopelia senegalensis*. Maize comprised a large proportion of the diet of these species and losses at one ostrich feedlot were estimated at over R 17 000 in two years. Dependence on artificial food sources was generally greatest in winter and spring, but economically significant damage was not confined to this period.

Alpha-chloralose showed good potential for reducing numbers of problem birds at livestock feedlots. However, the dynamic nature of problem bird populations favours a non-lethal management approach. Reduction of feed loss through manipulation of the ostrich ration could provide a relatively cheap and effective alternative to lethal control if applied appropriately.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

LIST OF PLATES

LIST OF APPENDICES

Page

ACKNOWLEDGEMENTS

I would like to extend my sincere thanks to the following people for their assistance at various stages of this project.

To my supervisors, Professors Adrian Craig and Pat Hulley, for sharing their passion for birds and birding, for many hours help in the field and for their continued guidance and constructive criticism of the various drafts of this manuscript. I would also like to express my sincere appreciation for their friendship and warm hospitality during my stay in Grahamstown, and especially for guiding me towards a career that is proving to be both challenging and highly rewarding.

To Hendrick Olivier for allowing me to work at Riverside Farm and to Andre Roets, his manager, for his generosity in giving me the run of both his feedlot and his house, for his continued interest and assistance in many aspects of my work, and for numerous memorable evenings at the Golden Valley Hotel.

To Allan and Marié Collett of Katkop for inviting me into their home and lives and allowing me free reign on their farm ...... and to Chester who was a constant companion.

To Hugh Collett of Lowlands Estate for allowing us the use of Terminus Country House on several occasions.

To Mandy and the late Cedric Biggs for allowing me free access to Brandeston and to Ash Davenport for allowing me to trap birds at Resolution Hatchery.

To Mrs Willi Howe for helping us track down our first quelea, for generously allowing me access to all her personal records and notes on quelea, and most importantly for her infectious enthusiasm for all things feathered.

To Dr C.J. Skead for his interesting and valuable correspondence on quelea and agriculture in this region.

To Luka Geertsema for his continued interest in this work and for organising financial assistance, through the Department of Agriculture, for part of my field work.

To Dr Richard Allan for providing unpublished plumage data for quelea collected in Botswana.

To Dr Chris Brown whose enthusiasm for ringing provided me with much appreciated companionship and assistance towards the end of my fieldwork.

To Bo Bonnevie for his assistance both in the collection and the analysis of quelea moult data.

To Dr Martin Villet for invaluable statistical assistance above and beyond the call of duty.

To Mrs Estelle Brink and Tony Dold of the Albany Museum, Grahamstown for their expert assistance with plant and seed identification.

To Mrs Maureen Botha and Mr Pieter van Zyl for assistance in locating and interpreting ostrich slaughter statistics for the Eastern Cape.

To Malcolm Mason of Horticura for providing free alpha-chloralose samples for use in experiments.

To Henk Bouwman, Jaco Willemse and Colin Burke of the National Department of Agriculture for their assistance in getting samples of quelea from the Free State.

To Brian and Peter at Phoenix Roller Mills, Grahamstown, for providing information on and samples of stock feeds.

To all those farmers and extension officers who provided information on quelea and problem birds in general in the Eastern Cape.

To the South Africa Bird Atlas Project for providing data on quelea distribution and to all those who contributed records of quelea sightings to the SABAP, Diaz Diary and other publications.

To the Foundation for Research Development and Rhodes University for their much appreciated financial support.

To the master-craftsman, Terry Butterworth, for his assistance in building cages and assembling netting equipment.

To Isuzu Bakkie BGP 997 for starting first time every time, for keeping me on the straight and narrow and for bringing me back.

To Graham Steele, my brother Brendan Whittington-Jones (#3) and all the others who looked after my birds while I was away in the field.

To my brother, Kevin Whittington-Jones (#1), for his continued support and for selflessly volunteering his services as a critic and proof-reader a second time.

To my parents who got me to Rhodes University, kept me there and kept me going.

And last but not least to my wife, Lynn, without whose love, friendship and continued support throughout the long nights and seemingly endless days this would not have been possible. The end is finally in sight.

1 CHAPTER ONE

GENERAL INTRODUCTION

Red-billed Quelea *Quelea quelea* (hereafter referred to simply as quelea) are small highly gregarious and opportunistic weavers (Family Ploceidae), occurring in semi-arid regions throughout Sub-Saharan Africa (Ward 1964). They evolved to feed mainly on wild grass seeds including wild sorghum and wild rice, varieties of which are now cultivated as crops. Consequently, quelea and many other members of the Ploceidae are considered pre-adapted to become pests of small grain crops (C. Elliott, pers. comm.). Flocks may number several million individuals and they are considered one of the most numerous and destructive bird species in the world (Ward 1965). Quelea numbers are estimated at around 190 million in the Republic of South Africa alone and they were declared a notifiable pest by the South African Parliament in 1989 (Yeld 1993). Between April 1997 and March 1998 more than 75 million quelea were killed by the National Department of Agriculture at a cost in excess of R3 million, thereby preventing an estimated R10.5 million damage to cereal crops (Geertsema 1998). Other bird species mentioned in this study will be referred to by their common and scientific names at first mention and thereafter by their common names alone. The common and scientific names of these birds are given in Appendix 1.

Over the last century quelea have expanded their range considerably in many areas of South Africa (Naude 1959; Berruti 1995), and in part this appears to be the result of environmental modifications brought about by changing agricultural practices. Increased reports of quelea in the Eastern Cape Province during the 1980s suggest that they have expanded their range still further. Though long considered a marginal area for the species, characterised by small vagrant flocks (Skead 1965a), quelea now seem to be more common, to occur in larger flocks and to be present throughout the year in some areas. It is important to verify this perception and to evaluate the current and potential future pest status of quelea in the Eastern Cape and to consider the suitability of methods of control and damage reduction for use in this region.

In order to answer these questions the main objectives of this study were:

1. To determine the current distribution of quelea in the Eastern Cape and to assess whether the distribution and abundance of this species have changed in the region in recent decades.

2. To determine whether quelea in the Eastern Cape represent an isolated, sedentary population, or whether large-scale interchange is occurring with other quelea populations in southern Africa.

3. To estimate the loss of stock feed to quelea and other granivorous birds at feedlots and to assess their dependence on this food source.

4. To assess management options for reducing bird damage in this region.

One of the first important aspects of this work was therefore to assess the current distribution and status of quelea in the Eastern Cape, and if possible to identify key factors which may be facilitating this apparent range expansion. This work forms the basis for chapter three and has been published (Whittington-Jones 1997).

To a large extent the movement patterns of quelea over much of their traditional distribution range appear governed by the availability of food (Lourens 1963; Ward 1971; Jones 1989a; Jones *et al.* 2000). Feedlots, which have recently become much more common in the Eastern Cape (T. Biggs, pers. comm.), provide an unusually abundant and reliable food supply which is available for much of the year. This artificial situation is likely to affect quelea behaviour with regard to timing and extent of movements, and this has important implications for the management of pest populations. Movements were assessed through an intensive ringing program and the possibility of a more sedentary and isolated population in the Eastern Cape was tested by comparing breeding and non-breeding plumage and morphological characteristics of local birds with those from other areas. These data are reported in chapters four and five.

The dry winter period is the most critical time of year for quelea and large numbers are thought to die as a result of starvation (Vernon 1989). Quelea tend to concentrate where food supplies are good (Vernon 1989) and as local food supplies become exhausted, flocks must move in search of new feeding areas. Where crushed maize or other cereals are fed to domestic livestock, this presents an abundant, often year-round, supply of food which may also be exploited by quelea, particularly towards the end of winter when natural food supplies are becoming scarce (Jarvis & Vernon 1989a; J. Collett, pers. comm.). Until recently however, it was not appreciated to what extent quelea may have become dependent on this food source (Berruti 1995). Since the livestock are consuming feed, losses to granivorous birds are initially not as obvious as with field crops. Perhaps understandably therefore, while millions of Rands are spent each year on protecting valuable cereal crops from bird damage (Geertsema 1998), no attempt has been made to assess the value of damage caused by birds at feedlots. Following the growth in the ostrich industry in the 1980s, feedlots became widespread in the Eastern Cape (Marx 1995) and while ostriches are no longer as popular in the late 1990s, ostrich and cattle (both beef and dairy) feedlots are still widespread, and there is an urgent need for means of making accurate damage assessments. Bird depredations at intensive animal husbandry units have long been of concern in Europe and America (Besser *et al.* 1968; Feare 1975; Feare & Swannack 1978; Feare & Wadsworth 1981; Glahn *et al.* 1983; Gramet & Dubaille 1983; Feare 1984; Feare *et al.* 1986) and existing models for assessing stock feed losses were modified to suit local conditions. Although quelea were frequently the most visible species at the feedlots in the Eastern Cape, a wide variety of other birds also utilise this resource. Diet and loss of stock feed to quelea and other important granivorous bird pests is dealt with in chapter six.

Lethal control methods (poisons and explosives) currently employed against large concentrations of quelea threatening ripening crops are inappropriate for the smaller flocks of mixed species that utilise feedlots. Unless populations are isolated, killing pest birds rarely produces any long-term relief (Dolbeer 1986). For management strategies to be effective (successful at reducing damage and in terms of the costs involved), it is essential to first consider the biology of the species concerned. A sound knowledge of the movements and behaviour of problem species is essential to understanding why they are a problem and what solutions are likely to be most appropriate (Dolbeer 1986; Feare *et al.* 1986). There is, however, unlikely to be a single simple solution that is appropriate to all situations, at all times of the year. A variety of potentially useful management tools were therefore evaluated in chapter seven. Effectiveness was assessed in terms of potential reduction in losses, cost, and ease of implementation.

STUDY AREAS

2.1 INTRODUCTION

Three ostrich farms Katkop, Riverside Farm and Brandeston, located at wide intervals along the north-south axis of the Great Fish River in the Eastern Cape Province of South Africa were selected as the main study sites (Figure 2.1), although a number of additional farms in the surrounding areas were visited over the course of the study. Each farm was visited monthly between June 1997 and July 1999 to ring birds and to collect census data and samples for gut content analysis. Although more study sites would have been preferable, this would not have been possible due to time constraints and it was hoped that data collected over a wider area, rather than from several nearby farms, would provide information that would be more broadly applicable to farmers throughout this region.

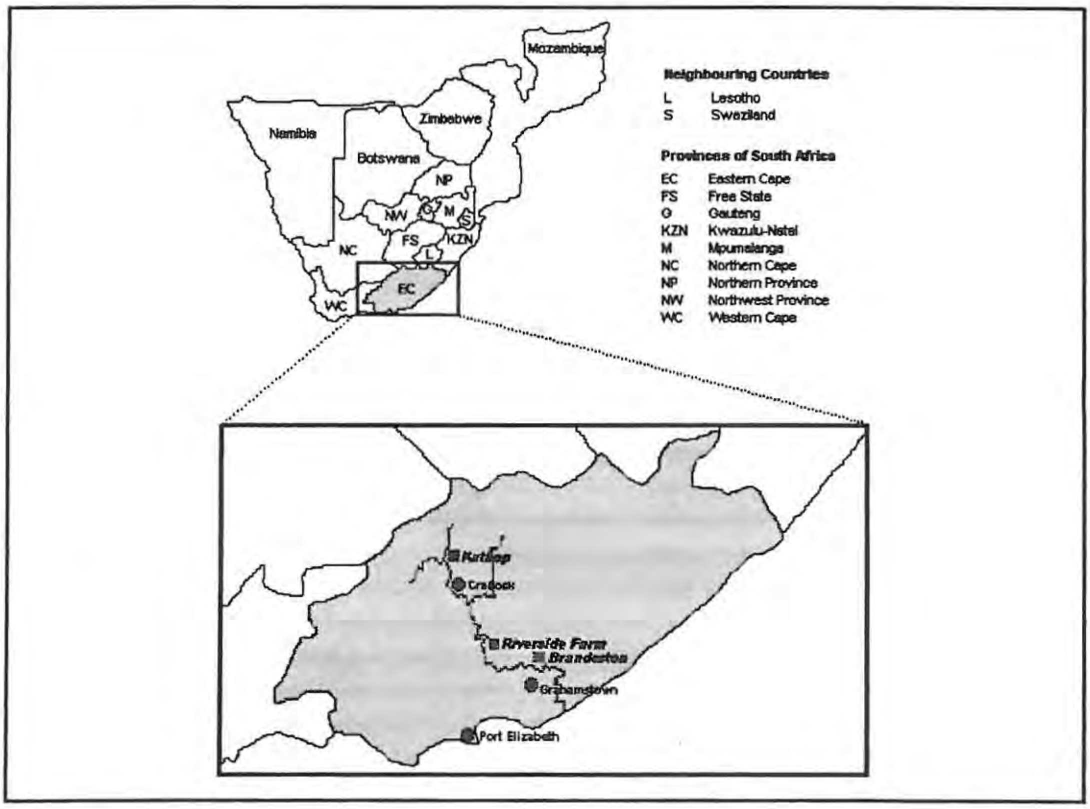


Figure 2.1 Map of Southern Africa with the Eastern Cape enlarged to show the Great Fish River and the location of Katkop, Riverside Farm and Brandeston.

2.2 BRANDESTON

Brandeston (33°06'S; 26°30'E), the most southerly site, is located near Fort Brown (Figure 2.1). This area borders on the Great Fish River Nature Reserve and its vegetation is characterised by Acocks (1975) as Valley Bushveld. There is little crop cultivation and most farms are dependent on livestock (ostriches, cattle, sheep and goats) and game farming. Intensive rearing of ostriches in feedlots was common until the late 1990s when a drop in the value of ostrich products forced many farmers to sell off their birds. Game farming has become increasingly popular and several farms, including Brandeston, have since been amalgamated to create a private reserve.

The Great Fish River forms the eastern boundary of Brandeston and is bordered on the western bank by narrow reed beds *Phragmites communis* and tall *Acacia karroo* trees. The eastern side rises up into a steep cliff along the length of the farm. The study site comprised 11 ostrich pens of varying sizes (Figure 2.2). Two of the smaller pens had covered areas for sheltering young ostriches, but the remainder, used mainly for adult birds, were open except for clumps of trees (Plate 1). Water was available from the river and numerous concrete drinking troughs in the ostrich pens and surrounding veld.

Plate 1 Ostrich pens at Brandeston with steep cliffs bordering on the Great Fish River in the background.

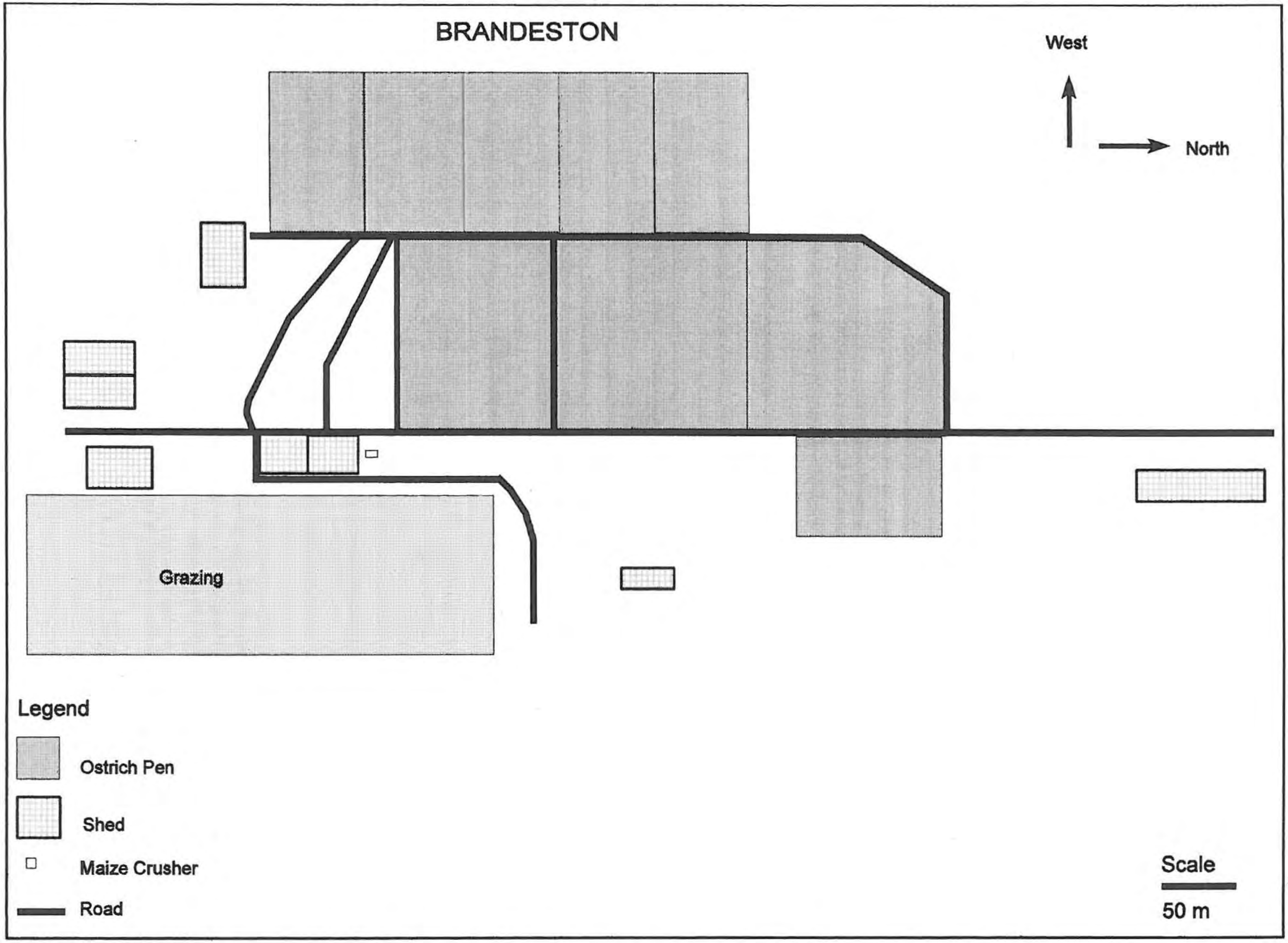


Figure 2.2 Map showing the layout of the ostrich feedlot at Brandeston.

Vegetation within the camps and surrounding veld is typified by a variety of thorny trees including *Acacia karroo*, *Azima tetracantha*, *Lycium austrinum*, and *Carissa bispinosa*, and various invasive cacti including Queen-of-the-night *Cereus jamacaru*, Prickly Pear *Opuntia ficus-indica* (L.) Miller and Jointed Cactus *Opuntia aurantiaca* Lindley. Other common species included *Portulacaria afra*, *Boscia albitrunca* and *Aloe ferox*. A wide variety of grasses, particularly *Setaria* sp. and weeds such as Goosefoot *Chenopodium* sp., Pigweed *Amaranthus* sp., and Thorn Apple *Datura stramonium* rapidly invaded empty ostrich pens and a small irrigated land, forming a dense undercover where ostriches and goats had been excluded.

Natural food supplies of seeds and fruits varied seasonally but were most abundant from about December to May (pers. obs.). Fruits of the cactus *Cereus jamacaru* provided a particularly abundant food supply to a range of species between January and April (pers. obs.). Ostriches were initially fed a typical maintenance ration of crushed maize (high energy component) and lucerne (July 1997 to February 1998) but the maize component was later replaced by cheaper whole barley (March to May 1998) and then whole maize (June to July 1998). From August 1998 to when the final ostriches were sold in March 1999, only a small amount of whole maize or barley was fed with a mixture of chopped sisal, lucerne and chicken manure. Throughout the period that crushed maize was fed to ostriches, numerous granivorous birds of a variety of species were seen feeding around the milling machine.

Lowest mean maximum and minimum temperatures were recorded over winter (June-August) while highest temperatures were recorded in summer (December- March). Temperatures in autumn (April-May) and spring (September-November) were intermediate. Although variable between years, rainfall generally peaked between October and December, with a lesser peak between February and April. Over the dry period (May-August), average rainfall was below 20 mm per month. Mean annual rainfall between 1981 and 1998 was 452.2 mm with slightly below average figures for 1997 (410 mm) and much wetter conditions in 1998 (523.3 mm). Mean rainfall and temperature data (Agricultural Research Council (ARC), Stutterheim) are summarised in Figure 2.3.

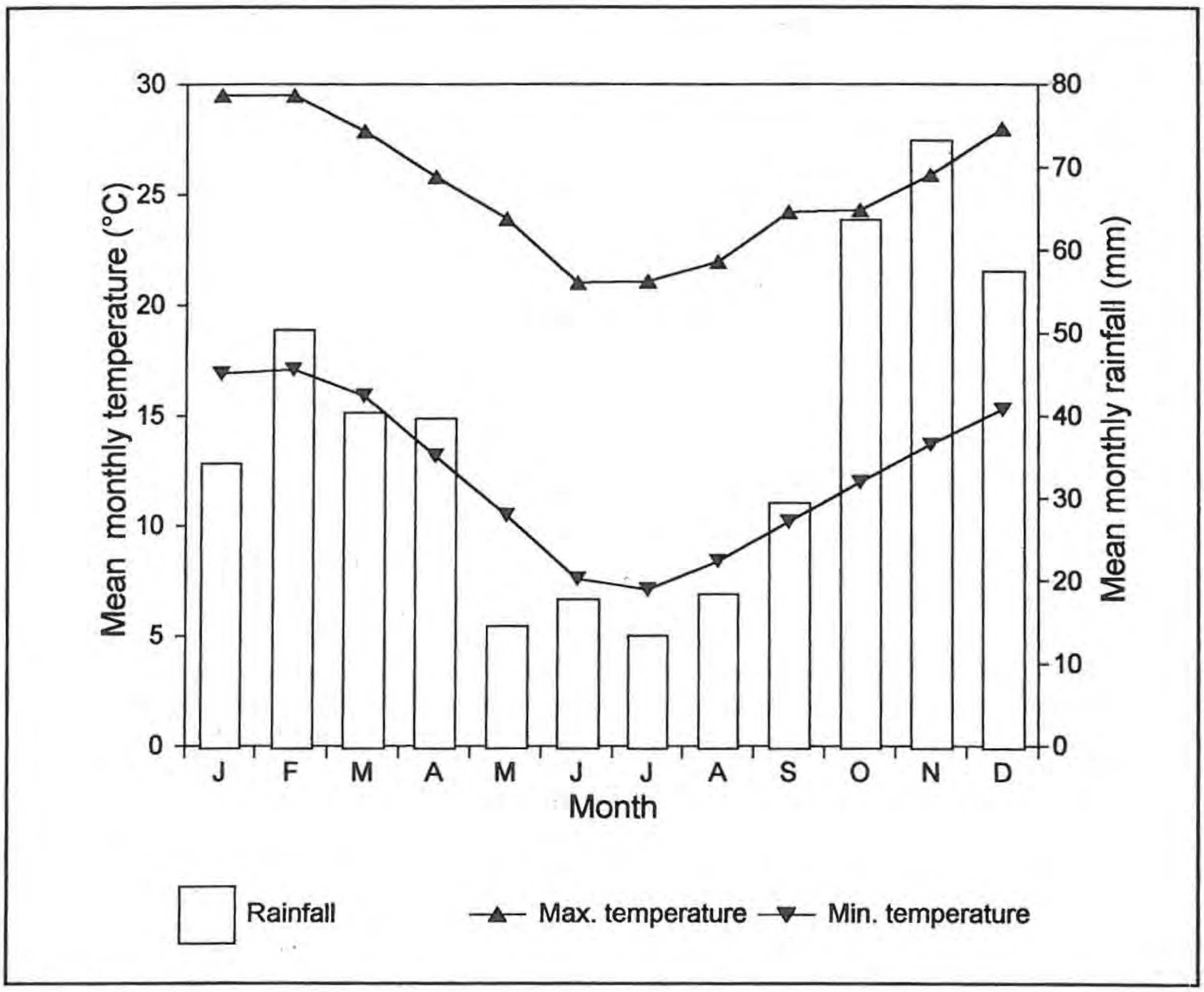


Figure 2.3 Mean monthly rainfall and temperature data from Fort Brown (1981-1999).

2.3 RIVERSIDE FARM

Riverside Farm (32°46'S; 25°50'E) is near Cookhouse, approximately 90 km west-northwest (about 220 km upstream) of Brandeston (Figure 2.1). Although the vegetation has been described as False Karroid Brokenveld and Valley Bushveld (Acocks 1975), it has been greatly modified by agriculture (Plate 2). This area is much better suited to arable farming than the Fort Brown area and while irrigated wheat (August to December) and maize (January to May) are grown seasonally, large areas of lucerne are irrigated throughout the year. In addition to crops, livestock such as sheep, goats, cattle and dairy cows are raised on natural or planted grazing lands while pigs and ostriches are reared intensively in feedlots (Central Statistical Services, Pretoria; A. Roets, pers. comm.; pers. obs.). The extensive piggery on the farm neighbouring Riverside Farm was recently completely enclosed with netting, and quelea are no longer considered to be a problem (M. Schulpfort, pers. comm.).

Water is available from large, earth storage dams, concrete troughs and the Great Fish River that borders the farm to the north, south and east. For much of its length, the western side of the river is bordered by reed beds *Phragmites communis* of varying widths and dense stands of tall *Acacia karroo*. The eastern side rises to form steep sand banks and tall cliffs along part of the farm's boundary, but the rest resembles the western bank. Easy access to the river, by humans, is limited to several causeways.

Large irrigated lands of lucerne, seasonal maize and wheat and occasional smaller areas of sugarbeet, beans, cotton, barley and canola occupied the fertile ground along the river throughout the study period (Plate 2). The remaining uncultivated areas appear to be composed of mixed grassland and thornveld dominated by small bushes and clumps of trees. The main tree species include *Acacia karroo*, *Lycium austrinum*, *Carissa bispinosa*, *Rhus* sp., *Boscia albitrunca*, and *Pappea capensis*. *Aloe ferox* and the invasive cacti *Opuntia ficus-indica* and *Opuntia aurantiaca* were found throughout these areas. Various grasses (*Echinochloa* sp., *Urochloa panicoides*, *Panicum* sp., *Digitaria* sp. and *Setaria* sp.) and weeds (*Amaranthus* sp., *Chenopodium* sp., *Solanum* sp., *Atriplex semibaccata*, *Rumex crispus*, *Salsola kali* and *Datura stramonium*) were abundant along roads, in empty pens, between fields, along irrigation canals and around earth dams. Apart from small numbers of pigs, sheep, goats and horses kept in two pens near the main homestead, ostriches were the only livestock on the farm.

Plate 2 Ostrich pens at Riverside Farm with irrigated lucerne lands in the background.

The ostrich feedlot itself comprised over 100 pens covering almost ten hectares, in roughly the centre of the farm (Figure 2.4). Where ostriches were kept at relatively high densities (60-100 per pen), pens were almost bare with only a few trees surviving. These were used as shelter by both ostriches and other smaller bird species such as quelea, weavers, starlings and doves during the midday heat. Empty camps were rapidly re-colonised by a variety of weed species including *Amaranthus* sp., *Chenopodium* sp., *Salsola kali* and *Datura stramonium*.

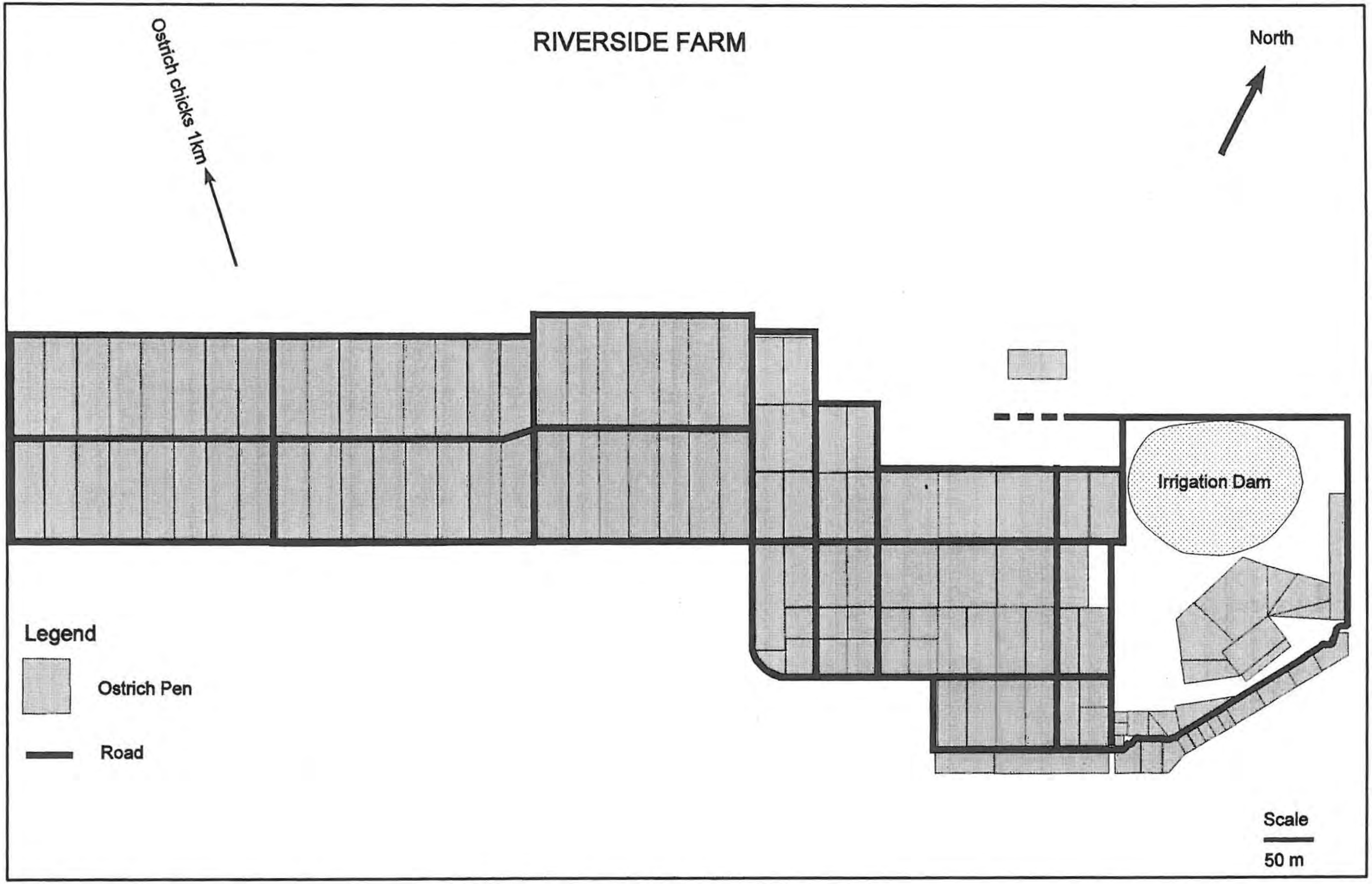


Figure 2.4 Map showing the layout of the ostrich feedlot at Riverside Farm.

Crushed maize was an important component in the ostrich ration throughout the study period except for March and April 1999 when only chicks received crushed maize each day. Food was available in open troughs (cut from old car tyres) throughout the day and was occasionally replenished in the evenings. Maturing wheat was available from about October to December 1998 and fields of maize stubble were utilised by various granivorous bird species for a few weeks after harvest each year (pers. obs.). Grass and weed seeds were abundant from early December until about April each year. Seasonal patterns of rainfall and temperature appeared to be similar to the Fort Brown area. Lowest mean minimum and maximum temperatures were recorded in winter (June to August) with highest temperatures in summer (December to March). Rainfall fell mainly in spring and summer with the driest period between May and August. Annual rainfall was again lower than the mean (353.3 mm) in 1997 (310.9 mm) but higher in 1998 (435.1 mm). Mean rainfall and temperature data are summarised in Figure 2.5 (ARC).

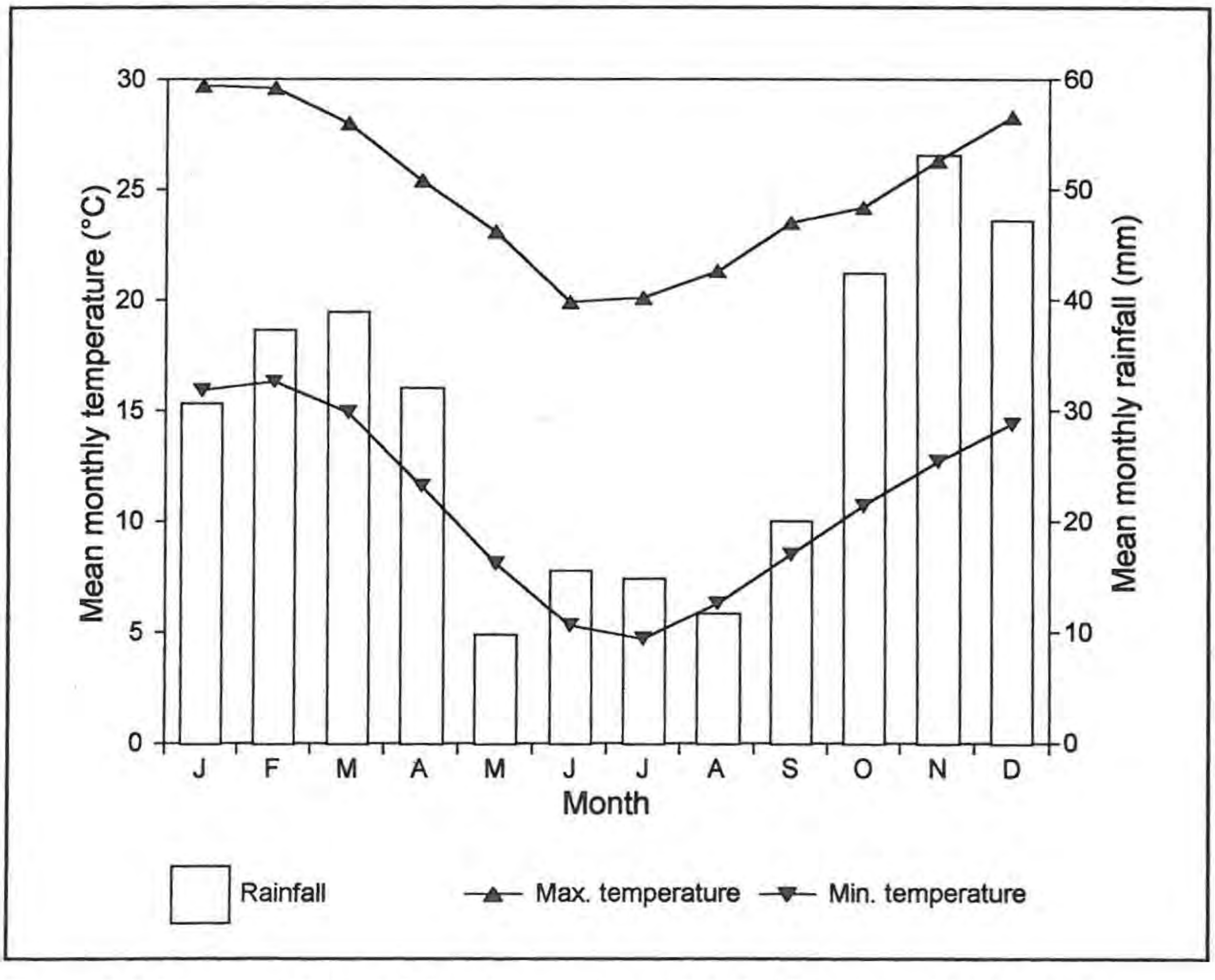


Figure 2.5 Mean monthly rainfall and temperature data for Cookhouse (1980-1999).

2.4 KATKOP

Katkop (31°53'S; 25°29'E) is located near the Fish River rail siding (Fish River), 30 km north of Cradock and approximately 90 km north-northwest (240 km upstream) of Cookhouse (Figure 2.1). This area is characterised as False Upper Karoo (Acocks 1975) but again has been extensively modified, especially on the floodplain of the Great Fish and Great Brak Rivers, by feedlots and cultivation of crops and grazing pasture (Plate 3). Individual farms are diverse with arable land and both extensive and intensive (feedlots) rearing of stock, but the area as a whole is fairly uniform (A. Collett, pers. comm.).

Plate 3 Katkop with both natural and transformed vegetation.

Irrigated winter wheat or barley and summer maize are the most important cereal crops. Lucerne and grazing pastures are grown under irrigation throughout the year. Cattle, sheep and goats graze the veld and at times are allowed access to the pastures and lucerne. Ostriches and small numbers of cattle are maintained on complete diet rations (mainly crushed maize and lucerne) in pens while a herd of dairy cows are grazed on irrigated pastures and fed supplementary rations (crushed maize) during milking. The ostrich feedlot at Katkop is relatively small, consisting of only three pens (roughly 60 m by 60 m), and has a capacity of around 300 slaughter birds (Plate 4). At times, young chicks were penned in small temporary camps in neighbouring lucerne lands and were provided with crushed maize supplements. Breeding birds were raised extensively on the veld and occasionally provided with whole maize supplements. The study area initially comprised of only the ostrich pens and surrounding fields (rotated between maize, lucerne and pasture) at Katkop (Figure 2.6). However, after crushed maize was removed from the ostrich ration at Katkop, mist netting of birds was concentrated first at the nearby cattle feedlot, then the cattle and ostrich feedlots on the neighbouring farm Lowlands Estate and finally at the Katkop dairy (established towards the end of 1997). Distances by road from the Katkop ostrich feedlot were 500 m, 2.5 km, and 1.2 km respectively.

Plate 4 Ostrich pens at Katkop.

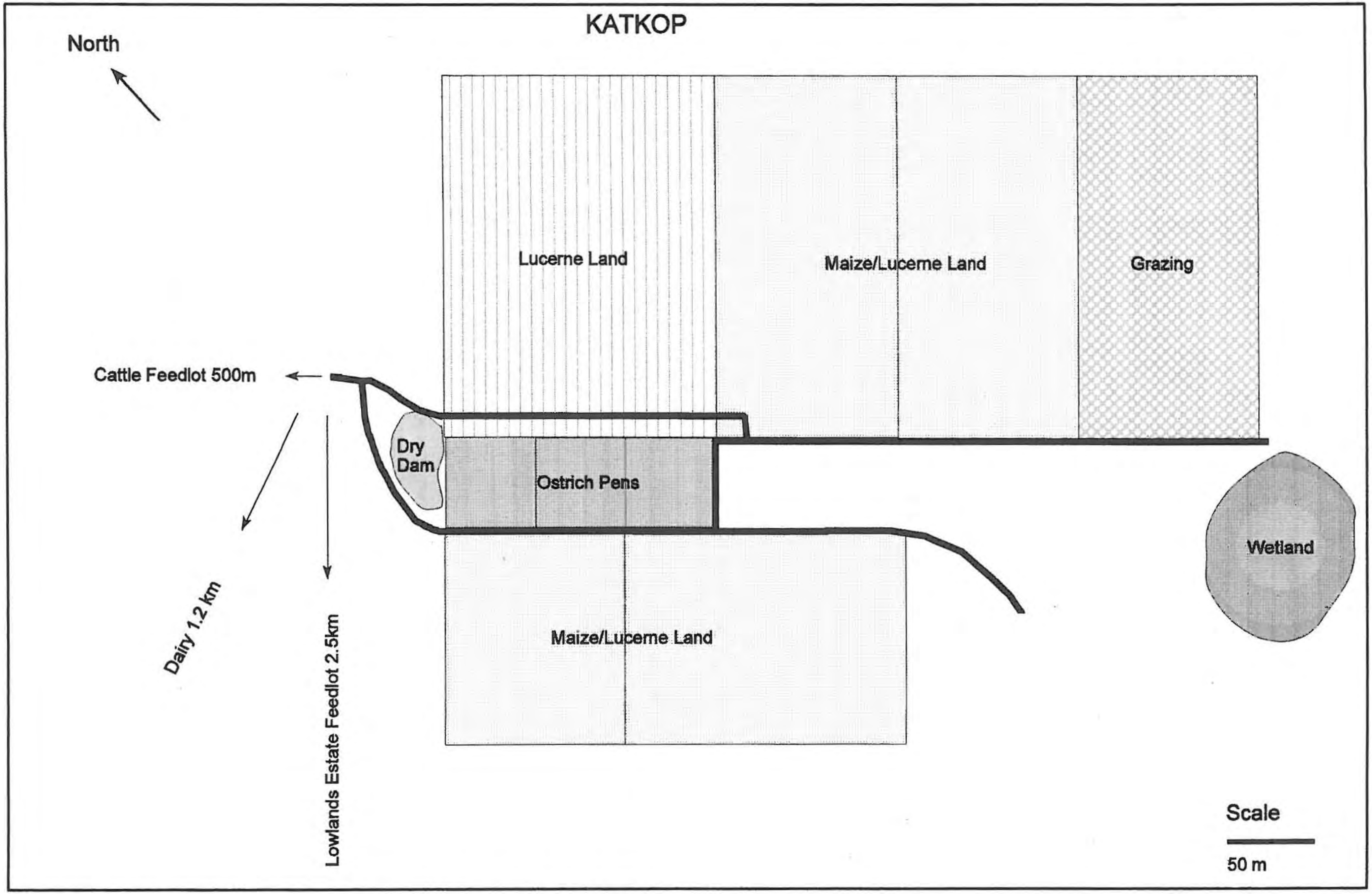


Figure 2.6 Map showing the layout of the ostrich feedlot at Katkop.

Natural bush still grows along the riverbanks and, as with the other two sites, reeds *Phragmites communis* and dense stands of *Acacia karroo* border the river. Thorny species such as *Lycium austrinum* and *Acacia karroo* are the most abundant indigenous trees and grow mainly along irrigation canals and where they have been left as wind breaks between fields. Seeding grasses are abundant in camps set aside for grazing, while weeds such as *Amaranthus* sp., *Chenopodium* sp., *Salsola kali* and Blackjacks *Bidens* sp., rapidly colonised empty ostrich camps and the edges of cultivated lands.

Several large earth dams for the storage of irrigation water, together with the river and cement drinking troughs provide abundant drinking water for birds. The practice of flood irrigation of both crops and pastures led to the development of several temporary wetlands that were utilised by a variety of bird species (pers. obs.).

Crushed maize was included in the ostrich ration at the Katkop feedlot from July 1997 to March 1998, but no maize was fed in April and May. Whole maize was provided from June to November 1998. Ostriches were given only lucerne from November until May 1999 when whole maize was briefly available before the feedlot was finally closed in June 1999. Cattle at Katkop were fed crushed maize in May and June 1998. Crushed maize was available at the Lowlands Estate feedlots for most of the study period although all the cattle and most of the ostriches were sold after February 1999. Because pastures were not burned, grass seed was available for much of the year. Dairy cows received maize meal and crushed maize in their supplement at the dairy until the end of the study. No wheat was grown at either Katkop or Lowlands Estate between 1997 and 1999, but crushed maize was available in stubble lands each year for several months after harvest.

Since no climate data were available for the Fish River area, rainfall and temperature averages for Cradock were used. Lowest mean minimum and maximum temperatures were again recorded between June and August and highest temperatures between December and March. Because of the great variability in rainfall even between neighbouring farms these data cannot be considered very representative for the area but do provide an indication of what might be expected. Rainfall data show a shorter and later rainy season for this area (November to March) than for the other two sites. Mean annual rainfall for the period 1988-1998 was 317 mm with above average rainfall in both 1997 (322.1 mm) and 1998 (365.4 mm). Autumn (April-May) is, however, considered the main rainy period on Katkop (A. Collett, pers. comm.). Climate data are summarised in Figure 2.7 (ARC).

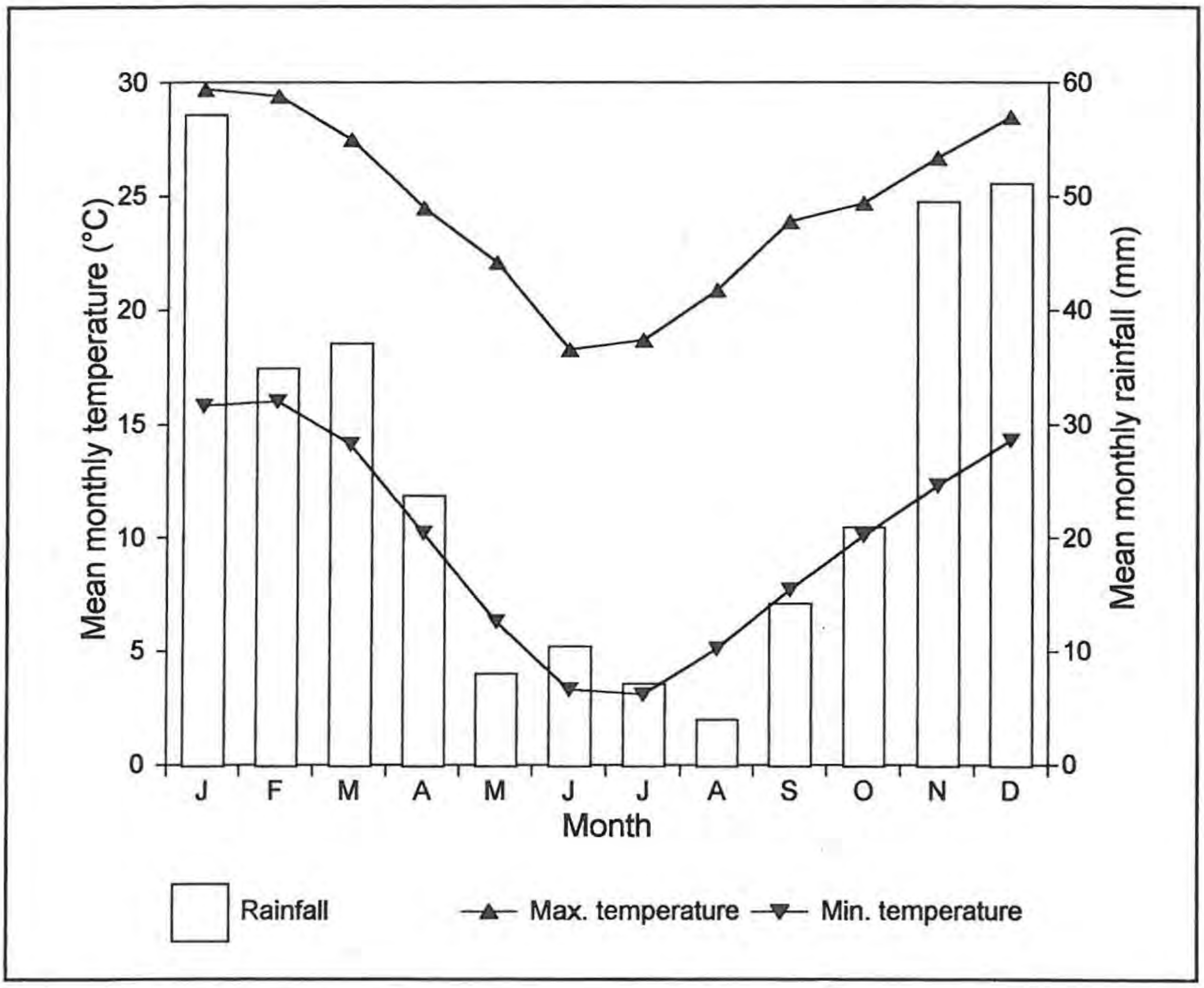


Figure 2.7 Mean monthly rainfall and temperature data for Cradock (1987-1998).

3 CHAPTER THREE

RANGE EXPANSION OF QUELEA IN THE EASTERN CAPE PROVINCE OF SOUTH AFRICA

3.1 INTRODUCTION

Since the mid 1980s the annual number of quelea sightings reported in the Eastern Cape Province of South Africa has increased dramatically, the number of records for 1986 alone exceeding all those prior to 1980. Not only have quelea been more frequently reported in the last two decades, but there are also indications that they now occur more widely than previously believed and that flocks are larger. Regular surveying of certain areas suggests that they may also have become more sedentary.

The increased number of reported quelea sightings may be attributed to a number of factors. Of these, more effective surveying and reporting following the initiation of the Southern African Bird Atlas Project (SABAP) in 1985 appears to be the most plausible. However, evidence from areas that have been well surveyed over the past century suggests that range expansion has indeed taken place, and alternative hypotheses therefore need to be considered. Better reporting also does not adequately explain apparent changes in the abundance of this species.

Lourens (1963) suggested that a lack of suitable natural food in the Karroid country and coastal sourveld regions limited movement of quelea south of 31°S. Skead (1965a) also attributed the low numbers of quelea in the Eastern Cape to an absence of an abundant food source. At this time arable farming in the region was minimal and most farmers concentrated on raising sheep and cattle. It is therefore hypothesised that changes in the availability of natural and/or artificial food sources would have been required to facilitate quelea expansion and population increase in this region.

Existing models of quelea movement patterns (Jones *et al.* 2000) propose that rainfall, principally through its effects on the availability (both timing and abundance) of grass seeds, the natural food of quelea, influences their movements. In years of good rains, seed production is good (Vernon 1989), thus changes in the number of reported quelea sightings, distribution and abundance of these birds may be the result of increased rainfall in the Eastern Cape in recent decades.

Quelea are also a notorious pest of artificial food sources such as small grain crops (Johnston 1907; Haagner & Ivy 1908; Schlupp 1922; Gill 1936; Naude 1959; Lourens 1963; Ward 1973a; Elliott 1989a; Erickson 1989; Jackson & Allan 1989; Jarvis & Vernon 1989a; De Grazio 1989) and livestock feedlots (Jarvis & Vernon 1989a; Berruti 1995; Berruti 2000) and are no longer entirely dependent on natural food sources for survival. Reports from elsewhere in South Africa and Zimbabwe suggest that increased quelea abundance and range expansion may be linked to agricultural changes such as increased crop cultivation and use of feedlots (Schlupp 1922; Naude 1959; Lourens 1963; Mundy 1989; Berruti 1995; Berruti 2000). Similar changes have been taking place in the Eastern Cape over recent decades and may have directly affected quelea populations.

The aims of this chapter were therefore firstly to collate and synthesise all known quelea distribution records for the Eastern Cape Province in order to determine whether there is indeed evidence to support claims that quelea have expanded their range, increased in abundance and become more sedentary in this region over the last century. Secondly, to determine which hypothesis: increased numbers of trained observers, increased natural food supplies (as a result of changes in rainfall) or increased artificial food supplies (as a result of changes in crop and livestock production) best explains these observations.

The Eastern Cape province is defined here as the area from Mossel Bay (22°E) in the west to the Kei River in the east and bounded by the Orange River in the north (Figure 2.1). The former Transkei region (hereafter referred to simply as the Transkei) falls outside the bounds of the Eastern Cape as defined here, but is included under the new political divisions and is thus briefly discussed.

3.2 MATERIALS & METHODS

3.2.1 Quelea distribution in the Eastern Cape.

The principal source of quelea distribution records was the original data set compiled during the Southern African Bird Atlas Project (SABAP) (1985-1992). This was supplemented by a careful examination of the published literature (*The Bee-eater, The Blythswood Review, The Bokmakierie, Diaz Diary* (newsletter of the Diaz Cross Bird Club), *Journal of the South African Ornithologists' Union, Ostrich, South African Avifauna Series, South African Journal of Natural History, Southern Birds* and Dr C.J. Skead's comprehensive work, Life-history notes on East Cape bird species (1940-1990) (1995), as well as his manuscript in the bird collection of the Albany Museum, Grahamstown) and the South African Nest Record Card Scheme. The personal notes and correspondence relating to ornithology of Dr J. Hewitt, late director of the Albany Museum, as well as the personal records of Professors A.J.F.K. Craig and P.E. Hulley (Department of Zoology and Entomology, Rhodes University), Mrs W. Howe, Dr D. Brown and more recently my own, were also included. Records provided by Eastern Cape Nature Conservation included those of the East London Museum and Albany Museum specimens, and the field records of Mr C.J. Vernon.

In the Eastern Cape the main spring/summer rainfall season overlaps two calendar years. Consequently, in order to determine the effects of rainfall during the main rainy season on the number of reported quelea sightings, the number of quelea sightings were calculated for the twelve month period after the expected start of the rainy season in October, rather than for each calendar year. To make other data comparable, number of observers and wheat and ostrich production were calculated for the same twelve month period from October to September.

3.2.2 Size and composition of quelea flocks.

Since there has been no attempt to estimate quelea numbers in the Eastern Cape in the past, it is impossible to make any direct comparison with the present situation in the region. There are, however, some historical records that provide details of the composition and size of quelea flocks observed during the period prior to the SABAP and these were compared with observations made during and after the SABAP.

3.2.3 Number of observers.

The number of observers who reported quelea sightings in each year was extracted from the literature and personal records listed above. The number of reported quelea sightings and the number of observers over each twelve-month period were compared by means of regression analysis.

3.2.4 Rainfall.

Rainfall data for the Eastern Cape were only available from 1921 to 1999 (South African Weather Bureau). Since the quantity of rain falling in the normal rainy season was assumed to have the greatest influence on grass seed production, mean monthly rainfall data for the period 1921-1999 were plotted in order to determine the main rainfall period for the Eastern Cape.

To determine whether rainfall, through its effects on grass seed production, may have contributed to the quelea's apparent range expansion and increased reporting in the Eastern Cape, total rainfall for each rainy season was compared, by means of regression analysis, to the number of reported quelea sightings in the Eastern Cape for the twelve months following the expected start of each rainy season.

To determine whether quelea were more common after seasons of above or below average rainfall, reported quelea sightings were first divided into three periods (before, during and after the SABAP) to control for the effects of dramatic changes in the number of active observers between these periods. In each period, the total number of quelea sightings in years (twelve months from the start of the rainy season) with above average rainy seasons were then divided by the number of years with above average rainy seasons for that period. The same process was repeated for years with below average rainfall in the rainy season. This effectively controlled for differences in the relative number of years of above and below average rainfall in each period (before, during and after the SABAP) and allowed number of quelea sightings per year of above or below average rainy season to be determined.

3.2.5 Crop production for Eastern Cape and surrounding areas.

Data for wheat production in the Eastern Cape were obtained from the Central Statistical Service, Pretoria and from the annual reports of the Wheat Board. Annual wheat production was compared to annual number of quelea observations by means of regression analysis. Wheat production seasons also overlapped calendar years and quelea sightings for corresponding time periods were therefore used in the analysis.

3.2.6 Ostrich production.

The number of ostriches raised annually in the Eastern Cape was estimated from slaughter statistics obtained from the National Ostrich Producers Association of South Africa, the Grahamstown Ostrich Abattoir and the monthly sales of ostrich tags (these tags indicate that ostriches are free of Newcastle Disease) in the province. Since ostriches are slaughtered at approximately one year of age (14 months), slaughter totals should give a fairly good idea of the number of birds raised each year. No distinction could be made between ostriches raised in feedlots and free-range birds, but the data does provide a useful indication of production trends for the region.

Annual ostrich slaughter statistics were compared to annual number of reported quelea sightings by means of a regression analysis to determine whether the increase in ostrich production in the region may have facilitated the spread of quelea into the region. The numbers of ostriches slaughtered were calculated for the twelve-month period from October to September to make it comparable with other statistics.

Additional agricultural information was obtained from Döhne Agricultural Development Institute, various Agricultural Extension Officers and through personal communication with a number of farmers. Dr C.J. Skead and Mrs J. Collett were particularly helpful regarding historical changes in agriculture in this region.

3.3 RESULTS

3.3.1 Chronological account of quelea sightings for new areas in the Eastern Cape Province (1910 to the start of the SABAP).

The first and most quoted record of quelea in the Eastern Cape is that of James (1921), who observed a breeding colony of several thousand birds nesting in a patch of "Mimosa" trees at Halesowen (Cradock District) on 5 April 1910 (Appendix 2). Colonies were later recorded in nearby Mortimer in 1917 and near Cradock in 1920 (James 1921). According to J. Collett (pers. comm.) flocks of quelea, sometimes quite large, were common visitors to the farm Katkop in the Fish River area in the 1920s and 1930s when wheat was grown and subsequently whenever grain was available. After harvest the quelea sometimes disappeared completely, or when the veld was in good condition they broke into small parties and fed on natural grass seeds. This pattern had continued until 1996 when she left the farm.

Although J. Collett never found any breeding colonies, Lourens (1963) is incorrect in his assumption that James' (1921) quelea breeding records for Cradock are the only ones for this species south of the Vaal for the first half of this century. Additional records of breeding at Cradock in April 1921, November 1926 and April 1928 (Nest Record Card Scheme) suggest that Cradock was a regular nesting site for quelea in the 1920s. Since then, only one case of suspected breeding (February 1987) and one of eggs in the nest (December 1987) have been noted for the Cradock District, although quelea are still frequently observed in the area (SABAP; pers. obs.). In May 1925 R. Godfrey reported receiving a pair of quelea (courtesy of R.F. Weir) collected at a breeding colony of several thousand birds at Peuleni (near Bolotwa, Transkei). The birds were seldom seen in the area at this time, and Godfrey still considered quelea no more than "erratic visitors" to the Eastern Cape Colony. He appealed to readers of the Blythswood Review to report any further sightings of this species in the region (Godfrey 1925).

Despite this appeal, only two additional reports were forthcoming for Cofimvaba (Transkei) and the nearby Queenstown area (Hewitt 1932), and Godfrey still referred to quelea as a northern visitor invading the area at "uncertain intervals" (Godfrey 1932). They are now, however, regarded as regular winter visitors to the Queenstown District

(Webster 1994), with some records for all months except February (SABAP). Although observed in the Graaff-Reinet District before 1935, only one specific record (for Kendrew in January 1954) appears to exist (Skead, unpublished manuscript). Since the initiation of the SABAP, however, they have been recorded in all months and are still regularly seen (B. Nash, pers. comm.). Quelea were only recorded once more in the 1930s. This record for Debe Nek (Middeldrift District) near King William's Town in December 1937 (Godfrey, East London Museum) was the southernmost yet.

In November 1941 quelea were first recorded for Adelaide. Their movement this far south was attributed to the drought further inland and although they built nests and remained in the area until January 1942, no breeding was reported (de Klerk 1942). Subsequently, large flocks were occasionally seen but quelea were still uncommon visitors to Adelaide in the 1960s (Taylor 1964). Two records collected by W. Howe in September 1995 and February 1996 are the only others known for this district.

The avifauna of the King William's Town District appears to have been fairly well studied in the early part of this century. Pym's (1909, 1915) surveys of the area produced a list of 335 species but did not include quelea. Godfrey (1918) was also very active in this area and although he produced useful summaries for a number of bird groups found in the Buffalo River Basin, no summary dealing with the weavers could be located.

Small flocks of quelea were reported for East London in January 1942 (Liversidge 1943) and this was followed by what appears to be the first published record for King William's Town in April 1944 (Godfrey, East London Museum). By 1945 monthly census returns for the Buffalo River Basin listed quelea as present in the area in at least eight months of the year (January-May, July, October and December) (Godfrey 1945). Surprisingly therefore, although further records were made for King William's Town in the 1940s (Godfrey, East London Museum) and 1950s (Skead, unpublished manuscript; Skead 1956; Skead 1995), quelea were last seen there in 1964 (Skead, unpublished manuscript). Similarly, quelea remained only sporadic visitors to East London until the 1960s (Courtenay-Latimer 1964) and have not been seen there since (SABAP).

During the 1950s quelea were recorded for a further eight new locations. These included Britstown and Lady Grey where quelea bred after 1952 (Lourens 1963), Aberdeen in October 1954 (D. Brown, pers. comm.), Fort Beaufort in December 1953, Middelburg in April 1955, Bedford in 1956, near Kei Road (Stutterheim District) in July 1956 and at Seven Fountains (Albany District) in September 1957 (Skead, unpublished manuscript).

While they remained sporadic visitors to Fort Beaufort at least until the mid 1960s (Taylor 1964), there seem to have been no further recorded sightings until 1989. Following a brief period (1989-1991) during which they were regularly seen in the area they have since disappeared once again (SABAP). In contrast, since 1988 quelea have become regular visitors to the Bedford District (W. Howe, pers. comm.; SABAP) and have bred on farms there on several occasions (Table 4.4).

Although several sightings were reported, quelea were not recorded for any new districts in the 1960s and only two towns, Goedemoed (July 1975) and De Aar (July 1976), both on the extreme northern boundary of the Eastern Cape, recorded quelea in the 1970s. This first record for De Aar was obtained during a year-long study (July 1976 to June 1977) of the avifauna of the De Aar district (Kieser & Kieser 1978) that produced sightings for all months except April and May. This would suggest that quelea are in fact regular visitors to the area, but the largest flocks observed contained only 20 birds and it is likely that they have been overlooked previously.

In the early 1980s (prior to the SABAP) first sightings were made for Komga in February 1981 (East London Museum field cards), Grahamstown (Albany District) in October 1981 (W. Howe, pers. records), Elands Heights (Maclear District) in December 1981, Niekerksberg (Somerset East District) in May 1982 (East London Museum road counts), Aliwal North in August 1983, nearby Bosberg (Rouxville District) in November 1983 (SABAP) and Pigott's Bridge (Albany District) in July 1984 (W. Howe, pers. comm.). Only one other record (December 1990) is known for Komga yet both of these confirm breeding (SABAP). This would suggest that quelea are more common than records indicate, yet they are unfamiliar to farmers in this district (Komga Farmers Association, pers. comm.).

3.3.2 Changes in known quelea distribution after the initiation of the Southern African Bird Atlas Project.

Since the initiation of the SABAP in the Eastern Cape in 1985, the known distribution of quelea has changed dramatically (Figure 3.1 and Figure 3.2). Originally considered to be a sporadic northern visitor during the early part of this century, quelea have since been recorded in coastal areas from the Qolora River Mouth on the border of the Transkei to Uniondale north of Knysna (Appendix 2).

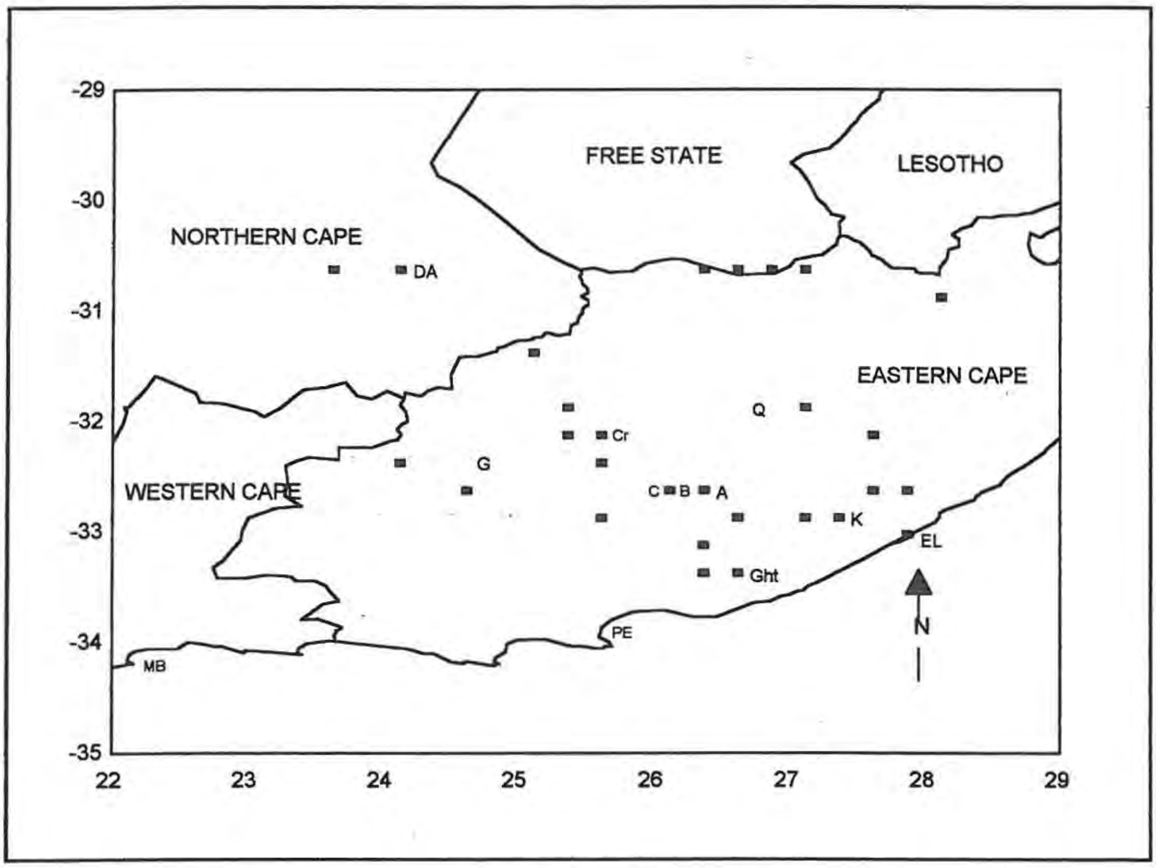


Figure 3.1 Reported distribution of quelea in the Eastern Cape 1910-1984. Boundaries indicate current political divisions and rectangles mark quarter-degree squares in which quelea sightings have been made. (A=Adelaide; B=Bedford; C=Cookhouse; Cr=Cradock; DA=De Aar; EL=East London; G=Graaff-Reinet; Ght=Grahamstown; K=King William's Town; MB=Mossel Bay; PE=Port Elizabeth; Q=Queenstown).

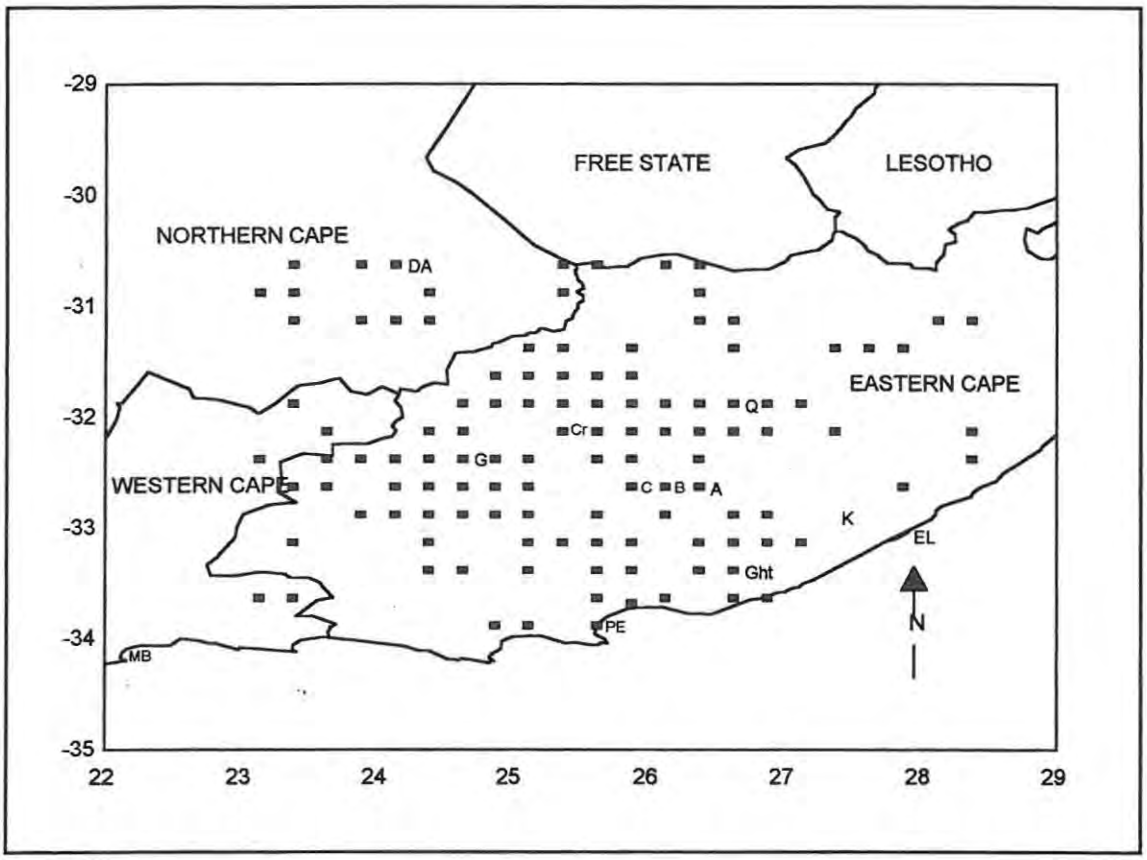


Figure 3.2 Reported distribution of quelea in the Eastern Cape 1985-1999; localities as in Figure 3.1.

Although quelea did not feature in Quinton & Winterbottom's (1968) comprehensive list of the birds of the Beaufort West District, they were subsequently observed at nearby Hopewell in May 1986 (SABAP). This, together with sightings at Haarlem (Uniondale District) to the south in March 1992 and Damfontein (Victoria West District) to the north in May 1992 (SABAP), seems to represent the current western boundary of quelea distribution south of the Orange River (approximately 23°E), although an unconfirmed report of Quelea as far west as Carnarvon (approximately 22°E) was made early in 1996 (L. Geertsema, pers. comm.). Along the Orange River itself, however, quelea have been recorded as far west as its estuary where breeding is thought to have occurred (Underhill 1998). The eastern boundary of quelea distribution in the Eastern Cape is less significant since they have been recorded for the Transkei and are regular visitors to KwaZulu-Natal.

In the Albany District (Appendix 2) Quelea were observed on the farm Brandeston during an initial visit to the ostrich feedlot in February 1997 and again, sometimes in flocks of several hundred, on 19 of 25 subsequent monthly visits to the farm between June 1997 and June 1999 (pers. obs.). In addition, a large flock of quelea was observed feeding in fields of birdseed on the farm Ryneath near Salem in October (A. Stephenson, pers. comm.) and November 1997 (pers. obs.), and approximately 200 quelea were seen feeding at a dairy feedlot near Sidbury in December 1997 (J. Gush, pers. comm.). These records, together with reports of several large flocks of more than 1000 quelea feeding in ripening sorghum fields in the nearby Kirkwood District in July 1997 (A. Nixon and P. Martin, pers. comm.), provide strong support for claims that quelea have expanded and begun to consolidate their range in the Eastern Cape.

3.3.3 Quelea records for the former Transkei region.

The earliest bird records for the Transkei (then still part of the Eastern Cape Colony) appear to be those of Davies who made extensive collections and observations of birds in the Port St. Johns, Lusikisiki, Flagstaff and Bizana areas of Eastern Pondoland during the period 1904-1906 (Davies 1907) and subsequently (Davies 1910). Despite recording Red Bishops and the considerably more rare Red-headed Quelea *Quelea erythrops* (nine specimens from at least two locations), Davies did not include Red-billed Quelea in his list of 287 species. Nor were quelea among the 242 species recorded for Port St. Johns in a much later study by Winterbottom & Hare (1947). Godfrey's records for Peuleni and Cofimvaba in the 1920s and 1930s, which have already been discussed, appear to be the only ones until quelea were observed feeding adjacent to grain lands in the Qolora River Mouth area in 1969 (Cooke & Cooke 1969). At the time they were described as relatively new to the district.

Twelve subsequent expeditions by the East London Museum to the Transkei between 1968 and 1975 produced no further quelea sightings (Quickelberge 1989) and only five additional records are available from SABAP. All of these are confined to the western half of the Transkei. A flock of quelea was, however, seen west of Matatiele (i.e. on the eastern boundary of the Transkei) in February 1985 (Quickelberge 1989), which suggests that they may occur sporadically throughout the Transkei.

3.3.4 Changes in the size and composition of quelea flocks.

In the period prior to, and even during the SABAP, very few of the reported quelea sightings made mention of flock size. This makes it difficult to assess whether flocks sizes and possibly quelea numbers have increased in the region in recent decades. Available information suggests that prior to the SABAP, quelea occurred mainly in small flocks dominated by other granivorous species such as bishops, canaries, sparrows, weavers, and widows (Table 3.1). However, undated observations for this period indicate that large flocks were occasionally observed in areas where food was locally abundant.

Table 3.1 Size of quelea flocks before, during and after the SABAP.

Flock description	Period		
	1910-1984	1985-1992	1993-1999
Large flock (≥100)	1 (7%)	5 (71%)	82 (58%)
Small flock (<100)	5 (33%)	0	41 (29%)
Flock dominated by other granivorous birds	9 (60%)	2 (29%)	19 (13%)
Total	15	7	142

During the SABAP, large flocks dominated and this trend has continued. After the SABAP, 58% of quelea flocks contained more than 100 birds, the largest of these numbering several thousand and even small flocks were predominantly comprised of quelea. Only 13% of these quelea sightings were of birds in flocks dominated by other granivorous species (Table 3.1). In most cases, these latter quelea were at feedlots where crushed maize had been removed from the livestock ration and thus the area was no longer able to support the large quelea flocks previously recorded there.

3.3.5 Observers.

The number of observers that reported quelea sightings in the Eastern Cape prior to the SABAP was generally low, but there was a dramatic increase over the SABAP period (1985-1992). As expected, the linear regression analysis showed a significant relationship (P=0.034) between the number of observers and the number of quelea sightings. As observers increased so did the number of recorded quelea sightings (Figure 3.3).

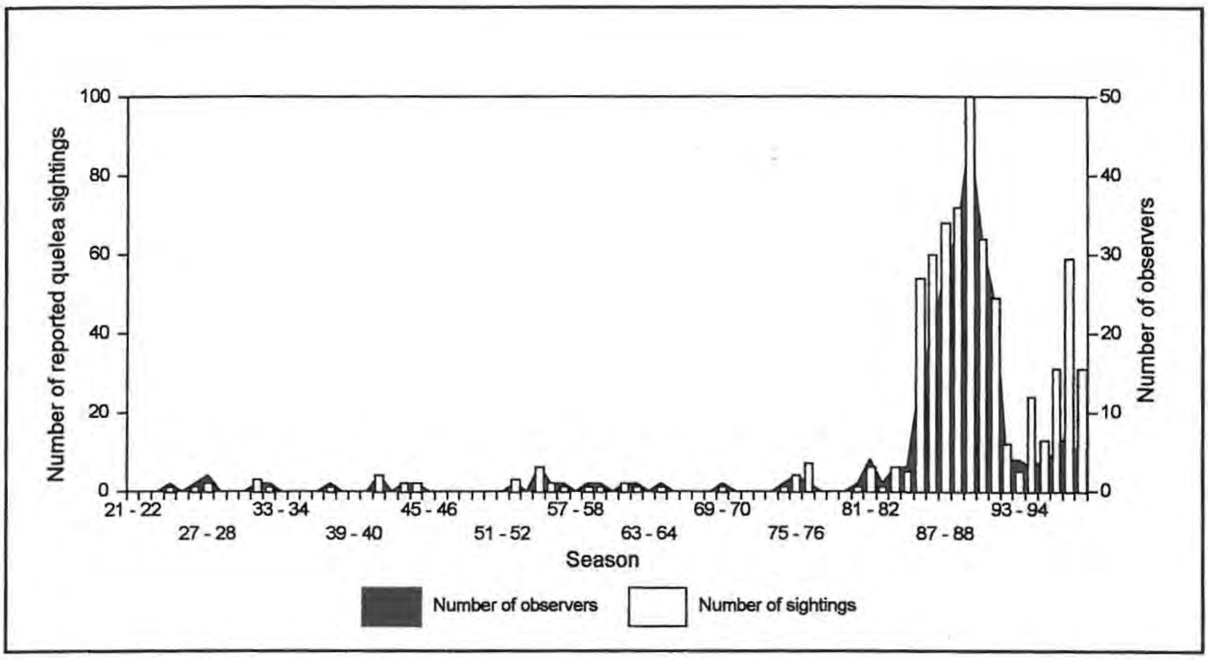


Figure 3.3 Number of reported quelea sightings in the Eastern Cape (1921-1999) plotted against the number of observers who reported quelea. Season refers to the period October to September.

3.3.6 *Rainfall.*

A plot of mean monthly rainfall between 1921 and 1999 showed that the main rainy season in the Eastern cape region was the six-month period between October and March (Figure 3.4).

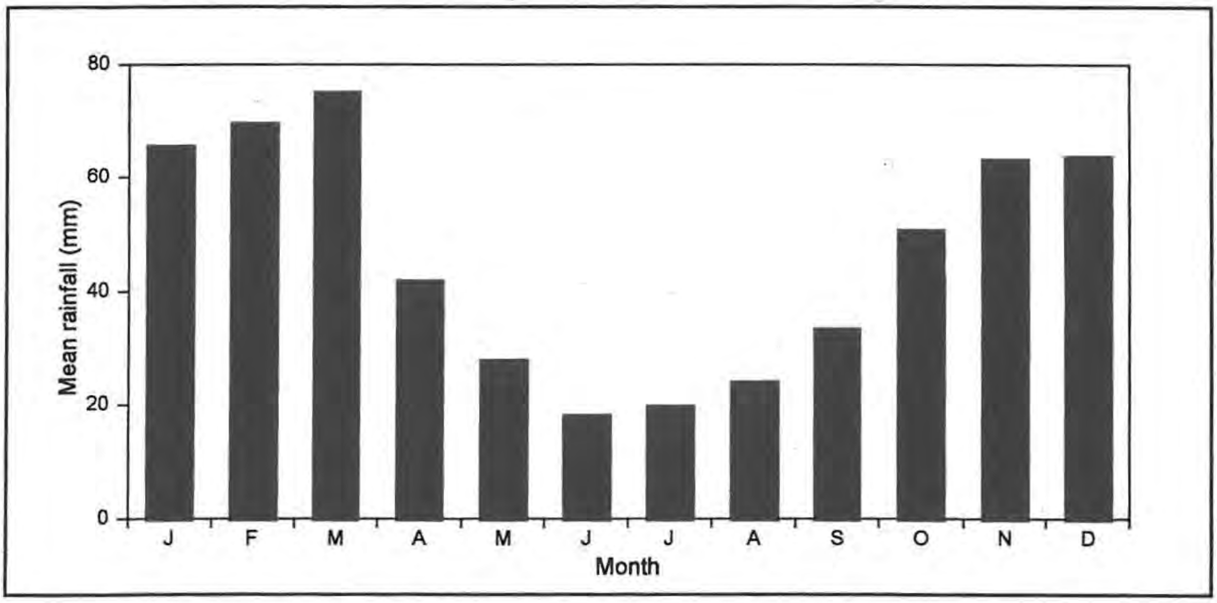


Figure 3.4 Mean monthly rainfall for the Eastern Cape (1921-1999).

Rainfall from October to March was quite variable between years in the Eastern Cape with no obvious trend towards increased seasonal rainfall over the last eight decades (Figure 3.5). In the absence of increased rainfall, it is considered unlikely that the availability of natural grass seeds would have increased significantly in the region in recent decades. It is therefore not surprising that regression analysis showed no significant relationship (P=0.904) between precipitation in the rainy season, and the number of reported quelea sightings in the twelve months between October and September (Figure 3.5).

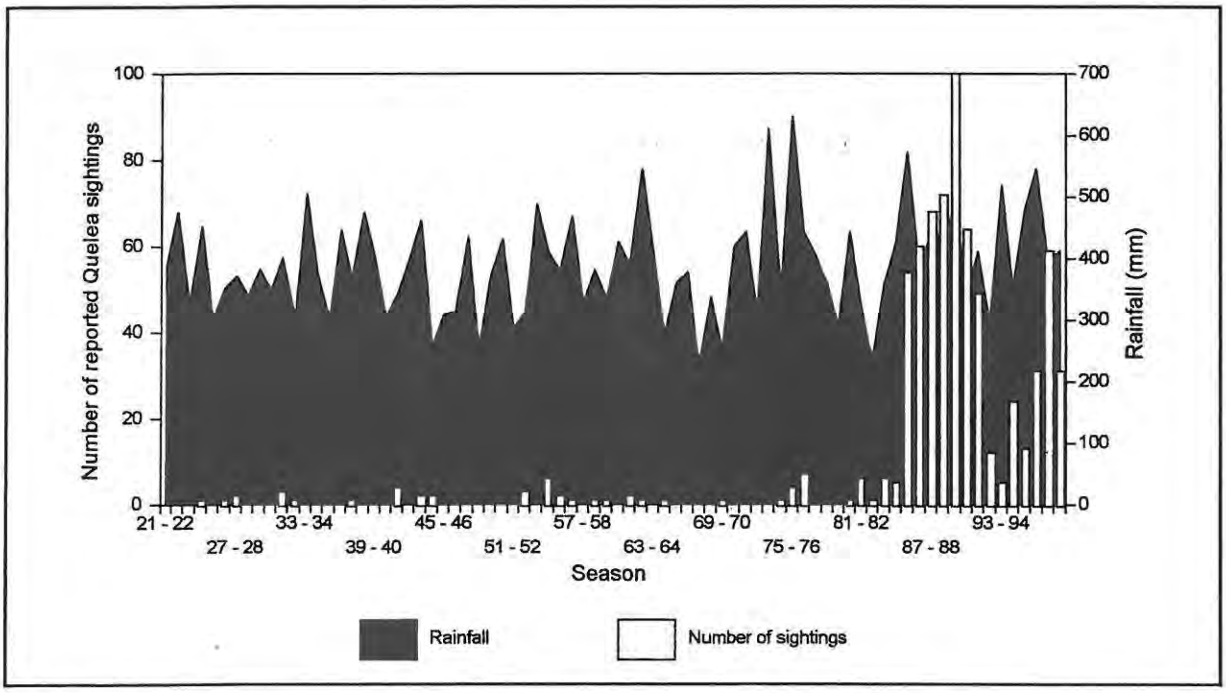


Figure 3.5 Number of reported quelea sightings in the Eastern Cape (1921-1999) plotted against rainfall during the rainy season (October to March). Season refers to the period October to September.

Average rainfall during the rainy season (1921-1999) was 400 mm. Although above average rainfall fell in only 35 (45%) of these years and below average rainfall in 43 (55%) (Figure 3.5), 65% of the 715 quelea sightings (4 additional records exist prior to available rainfall records) are from years of above average rainfall and only 35% from years of below average rainfall. This would appear to suggest that quelea were more common in years of above average rainfall when seed production was likely to be higher. However, most quelea sightings were during the SABAP, a period marked by above average rainfall in five of the eight years, and this would have biased the results.

Table 3.2 The number of years of above and below average rainfall before, during and after the SABAP and the number of reported quelea sightings in years of above and below average rainfall. The figures in parenthesis are the number of quelea sightings per year of above or below average rainfall for each period.

Period	Years of above average rainfall	Years of below average rainfall	Number of sightings in years of above average rainfall	Number of sightings in years of below average rainfall
1921-1984	25	39	30 (1.2)	34 (0.9)
1985-1992	5	3	291 (58.2)	183 (61)
1993-2000	5	1	142 (28.4)	35 (35)

Once disparities in the number of years of above and below average rainfall in each period were controlled for, the number of recorded quelea sightings in years of above average and below average rainfall was similar for each period (Table 3.2). Differences were greatest after the SABAP when against expectations, on average approximately seven more sightings were reported in years of below average rainfall (Table 3.2). This is not altogether surprising considering that most of the observations for this period were made in irrigated agricultural lands or feedlots, both providing food sources that are largely independent of rainfall.

Differences in the number of reported quelea sightings per year of above average and below average rainfall during the SABAP were small (3). Since surveys conducted during this period would have covered a wide range of both natural and agricultural habitats, it would appear that rainfall and hence natural grass seed production are not important factors in determining the number of quelea sightings in the Eastern Cape.

3.3.7 Crops.

Due to changes in the delineation of the regions for which crop production figures were collected by the Wheat Board and the Central Statistical Services (Pretoria), compatible data are only available from the 1951-1952 season to the 1993-1994 season. Data include all wheat produced in the area currently defined as the Eastern Cape, but overlap into parts of what is now the Western Cape and Northern Cape Provinces. However, since only wheat is considered in this assessment and other small grain crops such as oats, sorghum and birdseed are also grown in the Eastern Cape and are utilised by quelea, the figures for wheat production may still underestimate the total grain production in the Eastern Cape.

Wheat production was variable between years, but there was a general increase between decades with fairly consistent high levels of production during the 1980s and early 1990s when reported quelea sightings were most numerous (Figure 3.6). However, a linear regression showed no significant relationship between wheat production and the number of reported quelea sightings (P=0.94). Increased sightings of quelea reported after the initiation of the SABAP were therefore not directly correlated with higher wheat production.

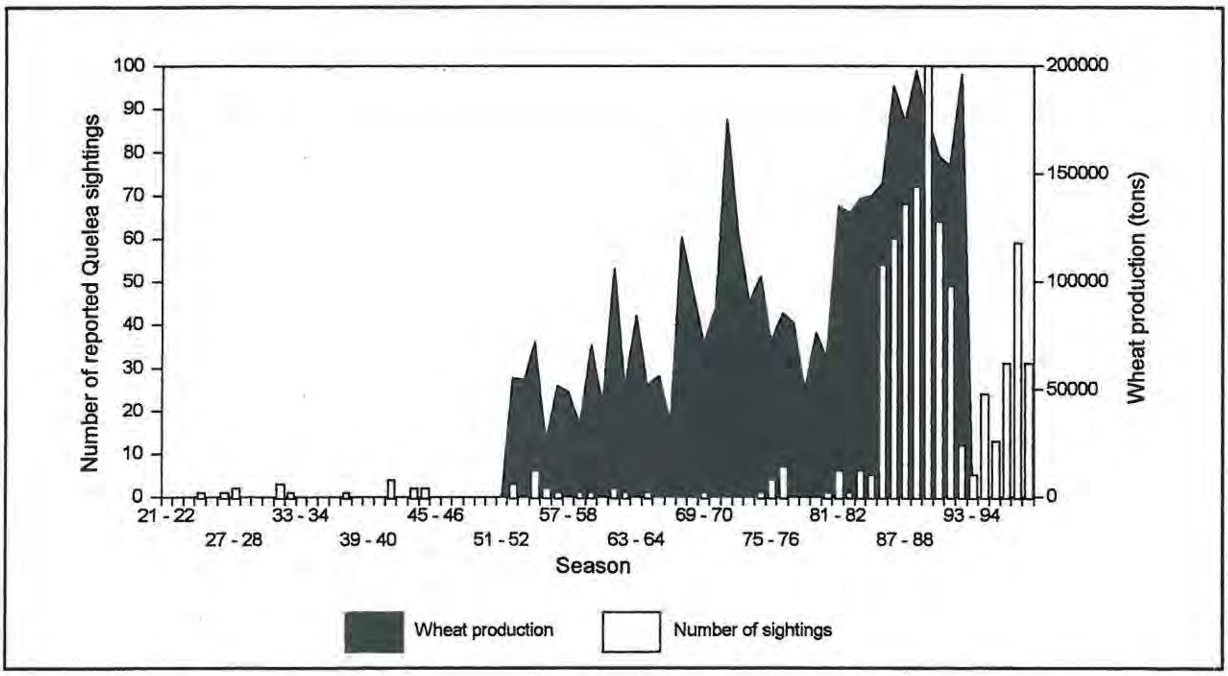


Figure 3.6 Number of reported quelea sightings in the Eastern Cape (1921-1999) plotted against wheat production for the province and surrounding areas.

3.3.8 Ostrich production.

Since the deregulation of the ostrich industry in South Africa in 1985, ostrich production has increased in the Eastern Cape, peaking in the 1996-1997 season. After this, a fall in the value of ostrich skins resulted in a drop in production and hence the number of ostriches fed in feedlots (Figure 3.7). Although the initial increase in ostrich production in the Eastern Cape coincided with the start of the SABAP and the increased number of active observers in the region, a linear regression showed no significant relationship (P=0.189) between ostrich slaughter figures and number of quelea sightings.

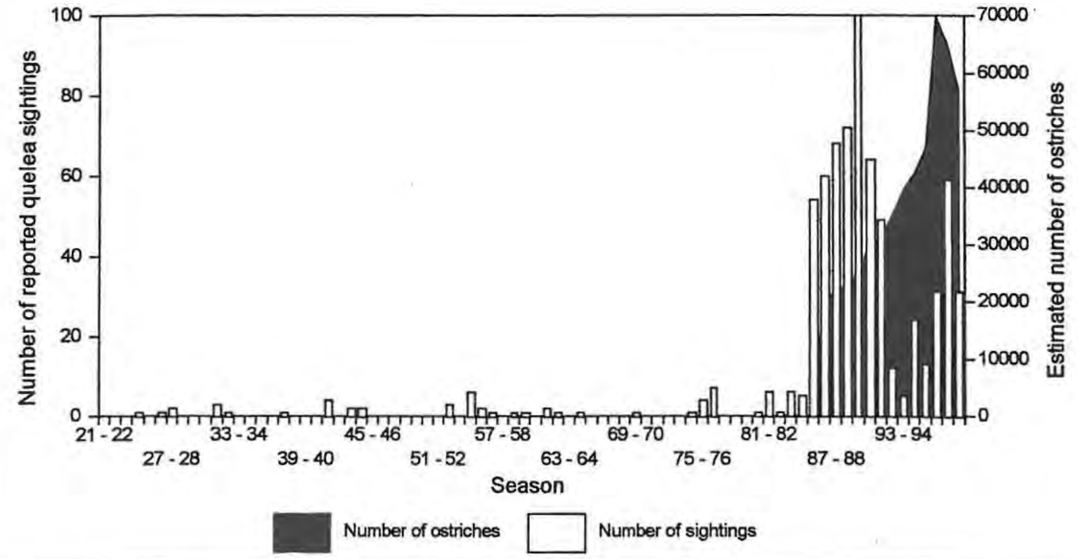


Figure 3.7 Number of reported quelea sightings in the Eastern Cape (1921-1999) plotted against the number of ostriches produced between October and September.

Dairy cows and cattle are also regularly fed at feedlots in the Eastern Cape, especially in years of poor rainfall, and thus the amount of feed available for birds such as quelea is likely to be underestimated in this study.

3.3.9 Number of sightings of quelea feeding on natural grasses and weeds as opposed to crops or in feedlots.

Only a small proportion of the recorded quelea sightings (approximately 17%) included reference to birds feeding. Very few observers reported quelea feeding on natural grasses or weed and in most cases (87%), quelea were found feeding in cultivated lands or at feedlots (Table 3.3). Crops included wheat, sorghum, oats, birdseed and canola. Although quelea were observed in maize lands, they appeared to feed mainly on weeds growing around the edges and between the rows. Quelea were reported to have eaten ripening maize on the farm Celva (near Cookhouse), but only after the kernels had been exposed by weavers (W. Howe, pers. comm.).

Table 3.3 Number of quelea feeding on "natural" as opposed to "artificial" food sources.

Source of food	Number of sightings
Natural grasses and weeds	15 (13%)
Feedlots, field crops	99 (87%)

Quelea were mainly attracted to ostrich or cattle feedlots, but were also seen in chicken and pig pens and on several occasions were even observed inside barns and sheds where animals were being fed or grain was stored. In all instances, quelea were seen to feed on the high protein grain component (crushed maize or barley) of the complete rations.

3.4 DISCUSSION

3.4.1 Influence of observer bias on the historical record of quelea distribution in the Eastern Cape.

Because of their sparrowy-coloured non-breeding plumage and their tendency to move with flocks of similar looking birds such as Red Bishops, Red-collared Widows *Euplectes ardens* and Red-headed Quelea, Red-billed Quelea may often go undetected by casual observers (Skead 1965a). Quelea records, especially during the non-breeding season, are therefore dependent on the observations of a few "knowledgeable individuals" (Skead 1965a). Indeed, all quelea records for the Eastern Cape prior to 1970 were made by eight individuals, and over 80% of these by H.W. James in the 1920s, R. Godfrey in the 1930s and 1940s and C.J. Skead in the 1950s and 1960s.

In light of this, while it is believed that this historical account is a fairly accurate reflection of available records, the small number of experienced observers actively reporting in this region prior to the initiation of the SABAP is of concern. With the exception of well-travelled routes and areas where quelea were regular visitors, it is unlikely that so few observers could have surveyed this region adequately. A further problem exists in areas where quelea have been extremely regular visitors. In the Fish River area (Cradock District) quelea are so common that farmers, although able to identify them, do not consider their presence sufficiently remarkable to merit recording (J. Collett, pers. comm.), or these records are never published.

After the start of the SABAP the number of observers increased dramatically. Consequently, much of the perceived quelea range expansion in the Eastern Cape may be attributable to the increased number of observers. This was the only one of several factors tested (number of observers, rainfall, ostrich production and wheat production) that was significantly related to the number of reported quelea sightings. Even so, as MacDonald (1986) found for the Pied Barbet *Tricholaema leucomelas*, it becomes difficult to determine to what extent apparent range expansion is an "artifact of the increased search effort" and to what it extent it may be attributable to other factors.

3.4.2 Range expansion.

While the presence of quelea continued to be reported for new locations into the 1980s, there was little evidence of consolidation of the "increased" range south of Cradock prior to the SABAP. Indeed, the available records appear to support Skead's (1967) hypothesis that quelea have always been present in low numbers through much of the Eastern Cape north of a line between East London and Somerset East. It was therefore not surprising that the increased number of active observers reported vagrant flocks over a much greater area in recent decades.

Areas such as the Albany District have, however, been regularly surveyed over the past century (Haagner & Ivy 1907; Paget-Wilkes 1924; Skead 1946a; Skead 1946b; Skead 1946c; Skead 1947; Skead 1965b; Diaz Diary) and the sighting of quelea on the farm Varnum between November and December 1981 (W. Howe, pers. comm.) appears to be one of the first records for the area. Unlike the earlier record of vagrants at Seven Fountains, this visit was followed by subsequent sporadic quelea observations in the Albany District throughout the 1980s and 1990s. Such records, though still not conclusive proof of true range expansion, do clearly show increased vagrancy of quelea beyond the southern limits of their range as proposed earlier by Skead (1967).

Indeed, a core area comprising the magisterial districts of Hofmeyr, Middelburg, Graaff-Reinet, Aberdeen, Cradock, Somerset East, Bedford, Fort Beaufort and Albany (Appendix 2) may be identified where quelea have been regularly observed. These districts accounted for more than 70% of the over 600 quelea records for this region prior to my own observations (SABAP). Most of these sightings come from districts along the Great Fish River, in particular Cradock and Somerset East. However, despite being visited by knowledgeable observers such as C.J. Skead, quelea were not recorded for the Cookhouse area (Somerset East District) prior to the 1980s. They now occur there throughout the year and consistently between years (Chapter 6), and may even breed nearby (Chapter 4), surely conclusive proof that this species has indeed expanded its range.

3.4.3 Influence of recent agricultural changes in the Eastern Cape in facilitating range expansion and increased quelea flock size in the province.

It has been estimated that up to 50% of the quelea population may die each year, many of starvation during the lean winter season (Ward 1964; Vernon 1989). They are, however, capable of finding extremely localised resources (Vernon 1989) and when natural food is in short supply at least some flocks are likely to be attracted to areas where winter grain crops are being grown or livestock are being fed, providing an abundant alternative food supply and possibly decreasing winter mortality.

Agriculture in the Eastern Cape during the 1960s focused mainly on raising cattle and sheep with minimal arable farming. During this period, quelea flocks remained small and presumably fed mainly on wild grasses and so went largely unnoticed by farmers (Skead 1965a). In the absence of large-scale grain production they were not considered economically significant and there appeared to be no build-up in the population (Skead 1965a). How then has agriculture in this region changed over the last two to three decades to produce the apparently marked changes in the distribution of this bird?

While increases in the number of reported quelea sightings in the Eastern Cape were not statistically explained by the increased wheat and ostrich production in the region over the same period, quelea were observed feeding on crops and in feedlots seven times more frequently than on natural grasses or weeds. Bearing in mind that weeds are to a large extent also the result of transformation of land for agricultural purposes, this observation agrees strongly with reports from the Bergville-Winterton area of KwaZulu-Natal where quelea were observed ten times more frequently in agricultural lands than in natural grasslands (Berruti 2000). The experiences of Schlupp (1922) and Lane (1930) in Potchefstroom (North West Province) also suggest that the change from predominantly pastoral farming to more intensive agricultural practices such as crop cultivation and intensive rearing of animals at feedlots has been and will continue to be crucial to quelea expansion in the Eastern Cape.

While it may be argued that quelea are more easily noticed when associated with agriculture, this is unlikely to be the whole explanation since Berruti's transects in

KwaZulu-Natal were specifically chosen to facilitate a comparison of the utilization of natural and agricultural landscapes by quelea (Berruti 1995; Berruti 2000). Whether quelea prefer farmland to natural habitats is debatable, but despite the absence of statistical support, these findings do provide good support for the argument that changes in agriculture have allowed quelea to expand their range into traditionally marginal areas.

Apparent increases in quelea flock size in the Eastern Cape cannot, however, be equated with the reported one to two order of magnitude increase in the size of the quelea population in the Bergville-Winterton area of KwaZulu-Natal since the 1970s (Berruti 2000). Large flocks of quelea have been associated with ripening grain crops in the Eastern Cape since the 1920s and 1930s (J. Collett, pers. comm.) and the increased frequency of large flocks being sighted in recent decades may merely reflect an increase in the number of feedlots and wheat fields where food is abundant. This has facilitated a concentration of previously dispersed flocks in areas where limited food supplies may not have allowed in the past, and does not necessarily mean that there has been an increase in the number of quelea in this region. However, the possibility of an increase in the quelea population in the Eastern Cape in recent decades should not be completely excluded.

Parallels may also be drawn with a number of other species including the Masked Weaver *Ploceus velatus* in South Africa (Brooke 1985), the European Starling *Sturnus vulgaris* in Britain and North America (Feare 1984; Palmer 1972), the House Finch *Carpodacus mexicanus*, (Palmer 1972), the Dickcissel *Spiza americana*, the Horned Lark *Eremophilia alpestris praticola* (Hurley & Franks 1976), and the Red-winged Blackbird *Agelaius phoeniceus* (Dolbeer 1990) in North America, the Eared Dove *Zenaida auriculata* (Murton *et al.* 1974), Spot-winged Pigeon *Columba maculosa* and Picazuro Pigeon *Columba picazuro* (Bruggers & Zaccagnini 1994) in Argentina, and the Collared Dove *Streptopelia decaocto,* the Laughing Dove *Streptopelia senegalensis* (under the name Palm Dove *Stigmatopelia senegalensis*), the House Sparrow *Passer domesticus,* and the Feral Domestic Pigeon *Columba livia domestica* in Israel (Mendelssohn & Yom-Tov 1999), all of which have benefited from man's modification of the environment for agricultural purposes.

Feedlots.

Prior to 1985, ostrich farming in South Africa was monopolised by the Little Karoo region (Bezuidenhout 1995), but the industry has since expanded enormously. Ostrich farming is now practised on a large scale in the Eastern Cape (Marx 1995) although a recent drop in the market value of ostrich products has resulted in the closure of many of the smaller operations (A. Roets, pers. comm.). Birds may either be free ranging (i.e. they feed off the natural vegetation) or housed and fed in open-air feedlots.

Supplementary feeding of cattle (Jarvis & Vernon 1989a; Berruti 1995; J. Collett pers. comm.) and ostriches (A. Collett, H. Olivier, O. Smith and B. Nash, pers. comm.) at feedlots, where crushed maize is one of the principal components of maintenance feeds, appears to provide a valuable food resource for a number of bird species including quelea. Indeed, quelea were recorded at cattle and ostrich feedlots in the Cookhouse and Cradock areas each month from July 1997 to June 1999 (Chapter 4), and crushed maize was one of the main components of their diet in all seasons (Chapter 6). Similarly, Berruti (1995) found that crushed maize from feedlots and fields constituted the single most important food item for quelea in the Bergville-Winterton area (KwaZulu-Natal) outside the breeding season.

The majority of the maize in the commonly used "Straight-run" beef-cattle feed and ostrich maintenance ration is less than 3 mm in size and therefore falls into the preferred size range of quelea (1-2 mm) (Ward 1965; Vernon 1989; Chapter 7). Feare (1984) observed that problems with European Starlings in cattle farming in Britain only arose with the introduction of intensive feeding of cattle at feedlots. As with the quelea, European Starlings tend to target the high-energy portion of the feed thereby affecting the dietary intake of the cattle (Feare *et al.* 1981).

Although the number of quelea sightings in the Eastern Cape was not significantly related to changes in the number of ostriches raised in the region, most sightings were from areas where large numbers of ostriches were being raised. Indeed, approximately 25% of ostrich farmers registered with the East Cape Ostrich Producers Association were from the Cradock and Somerset East Districts, the same districts where quelea were most frequently observed prior to the current study. The absence of ostrich production figures at a district-by-district level makes any further analysis of this relationship extremely difficult.

Following years of good rains, when the veld is in good condition, the need for supplementary feeding of cattle and other livestock is reduced. Low meat prices may further reduce the use of feedlots and at present it appears that only ostriches are being fed on any significant scale in the Eastern Cape (S. Biggs, G. Gush, J. Pistorius, pers. comm.).

Irrigated wheat.

While cultivated crops have completely replaced natural vegetation, and thus quelea food sources, in some areas (Mundy 1989), in others irrigated crops such as winter wheat may augment natural food sources seasonally (Vernon 1989). Provision of additional food during the critical winter period is believed to have increased survival of quelea in KwaZulu-Natal to the point where they have become pests (Berruti 1995).

Additional food sources also allow birds to expand their range into previously unsuitable areas or to remain longer in areas where a shortage of food previously made this impossible. Such a situation seems to have developed in the Northern Cape Province where quelea were not thought to occur earlier in this century. Now they appear to be resident in the Upington area and are feeding on irrigated wheat, maize and possibly even lucerne seeds, although the last-named seems unlikely (Meeting of the Red-billed Quelea Action Group, 1997).

The Orange-Great Fish River irrigation scheme which opened in 1974 (Collett 1982) changed the previously highly variable Great Fish River into a well regulated stream with year-round flow (Plate 5). This scheme has resulted in an increase in the extent of both arable land (Roux & van der Vyver 1988) and reed beds (J. Collett, pers. comm.) and hence the potential availability of food (irrigated wheat) and suitable breeding habitat for quelea and related species. An increase in the number of Red Bishops has already been noted in the Fish River area of the Cradock District (J. Collett, pers. comm.).

Plate 5 Great Fish River at Katkop with dense reed beds providing suitable breeding habitat for quelea.

Farmers have been cultivating irrigated cereal crops along the Great Fish River since the end of the 19th century (Collett 1982). The climate of the Great Fish River irrigation area is particularly suited to the growth of high quality Durum wheat that is used in the manufacture of pasta products (Smit 1996). Cultivation of wheat (particularly the Durum variety) in the Somerset East area of the Great Fish River was promoted only when sufficient Orange River water became available in the district (C.J. Skead, pers. comm.) and this still appears to be one of the most important grain crops along the Great Fish River (Roux & van der Vyver 1988; Smit 1996). While there is no conclusive evidence that increased quelea sightings in the Eastern Cape are linked to wheat production, quelea and other seed eaters are attracted to ripening wheat. Wheat production in the Somerset East District increased fairly consistently from 353 T in 1974 to 2679 T in 1988 (Census of Agriculture, CSS) and this may account for the apparent sudden appearance of quelea in this district in the early 1980s.

Reports of extensive damage to wheat by quelea have been received from both Cookhouse in the Somerset East District (G. Barnes-Webb, A. Roets and O. Smith, pers. comm.) and from Cradock (A. Collett, pers. comm.). Indeed, A. Collett has replaced his wheat with barley which has a stronger beard which he hopes may reduce quelea damage. During the 1970s, relatively small fields of irrigated wheat were also grown in many areas of KwaZulu-Natal and at lower altitudes than at present. Numbers of seed-eating birds increased annually until eventually many farmers stopped planting wheat (Berruti 1995).

Although the first published quelea record for Addo appears to be April 1990, P. Martin (pers. comm.) recalls seeing them in the area as early as 1985 and considers them to be mainly winter visitors. If this is indeed the case, it is possible that the extensive winter wheat fields observed by C.J. Skead (pers. comm.) in the surrounding areas in the late 1980s might be attracting them to the area. Moorcroft's (1992) report of two flocks of around 500 quelea feeding on oats at Addo Heights in September 1992 appears to support this theory.

Maize.

Although maize was not initially considered vulnerable to quelea attack (Lourens 1963; Ward 1973a; Winkfield 1989), Erickson (1989) reported that quelea fed on the soft kernels after the husks had been slit open by weavers. Reports from the Northern Cape Province indicate that quelea have now learned to strip the maize cobs for themselves (Meeting of the Red-billed Quelea Action Group, 1997). Recent observations on the farm Celva in the Cookhouse area show that quelea also feed on maize in this region (W. Howe, pers. comm.), but no reports of serious damage have yet been received. Indeed, as observed by Stark (1900) and Haagner (1905) early last century, most feeding flocks of quelea still appear to be attracted by the weeds and grasses growing between the rows of maize, rather than by the maize itself (pers. obs).

3.4.4 Additional changes that may have increased the suitability of the Eastern Cape as quelea habitat.

Several other factors, the effects of which are not as easily quantified as livestock and grain production, may also have influenced the suitability of habitat in the Eastern Cape and allowed quelea to expand their range.

Water availability.

Because of their requirement for daily drinking water (Jarvis 1989; Ward 1978), quelea are thought to migrate along river systems wherever possible (Jarvis 1989; Jones 1989b). Large movements of birds have been reported from amongst others, the Limpopo and Rhenoster Rivers (Northern Free State) (Lourens 1963) and the concentration of quelea observations along the Great Fish River suggests that it may serve a similar function in this region.

The development of alternative surface water sources such as boreholes and dams in previously waterless areas may have reduced much of this dependence on river systems (Bradfield 1932; Jarvis 1989). This has allowed quelea to exploit food sources in areas where the absence of daily drinking water would have previously excluded them (Jarvis & Vernon 1989a).

Influence of poor pasture management.

Overgrazing and excessive burning expose fallen seeds otherwise hidden by vegetation and promote the replacement of perennial grasses by annuals, which quelea are believed to prefer (Jarvis & Vernon 1989a; Chapter 6). Encroachment of woody species such as *Acacia karroo* into grasslands has been observed in many overgrazed areas of the Eastern Cape (Roux & van der Vyver 1988). This should further aid the spread of quelea into this region by increasing the availability of favourable roosting and nesting habitat (Lourens 1963; Vernon 1989).

3.5 CONCLUSIONS

Despite the obvious problems with the reporting of quelea sightings in the Eastern Cape, there is good evidence from areas that have been well surveyed in the past that quelea have indeed expanded their range and are now considerably more widespread in this region. Yet, while flocks now appear almost sedentary in certain districts such as Cradock and Somerset East during the dry winter period, they are absent from areas frequented in the 1950s and 1960s. In some areas, the disappearance of quelea may have been related to changes in land management practices that followed the establishment of the independent homelands of the Transkei and Ciskei. While in others, the absence of knowledgeable observers, or a lack of reporting may have contributed to a false perception that quelea were no longer present.

The frequency of quelea sightings increased after the initiation of the SABAP, but this could only be conclusively linked to the number of observers. Large numbers of quelea (more frequently reported after the SABAP) were generally associated with agriculture, but increases in wheat and ostrich production in the last two decades do not appear to have contributed significantly to increased quelea sightings. Increased sightings of large quelea flocks in association with small grain crops and feedlots therefore do not appear to be indicative of a larger Eastern Cape quelea population, but rather a more concentrated and possibly more sedentary one, at least during the dry winter season. Ripening wheat crops and ostrich feedlots are capable of supporting much larger concentrations of granivorous birds than equivalent areas of grassland. This is especially so at feedlots, where food may be practically inexhaustible while livestock are being fed, and large flocks may thus remain in a given area for extended periods.

4 CHAPTER FOUR

THE INFLUENCE OF PREDICTABLE FOOD AVAILABILITY AT LIVESTOCK FEEDLOTS ON QUELEA MOVEMENT PATTERNS

4.1 INTRODUCTION

Quelea are capable of extensive long-distance movements (Ward 1971). Birds ringed in South Africa have been recaptured as far away as Malawi (Lourens 1963) and the Democratic Republic of Congo (Oschadleus 2000), but generally appear to move shorter distances. Ward (1971) was the first to propose an underlying pattern behind the complex and apparently erratic movements of quelea. Long distance early rains and breeding movements may be distinguished from the more localised and nomadic movements of dry season flocks, the last being dependent on the patchy availability of food (Jones 1989a). Movement patterns appear broadly based on rainfall which affects supplies of green grass seed and insects, the main requirements for breeding (Ward 1971; Jones 1989a).

In the first half of this century quelea are thought to have undertaken a northward movement in early summer to the traditional breeding concentration areas along the Limpopo River and in Ngamiland in Botswana, followed by a post-breeding dispersal, with some flocks returning to the central plateau of south Africa for winter (Lourens 1963). During winter, flocks were generally small and nomadic (Lourens 1963) moving southwards as the dry season progressed (Jones 1989b). Movement further south than 31°S was thought to be limited by unsuitable vegetation (Lourens 1963), and influxes into marginal areas such as the Eastern Cape were attributed to drought conditions to the north (de Klerk 1942).

Increased cultivation of small grain crops on the central plateau of South Africa during the latter half of this century enabled more quelea to remain and breed in this area rather than moving north (Naude 1959; Lourens 1963). Arrival of additional quelea on the central plateau following the typical southward post-breeding dispersal further exacerbated problems in these areas. Birds dispersing from breeding colonies on the central plateau may have moved further south during the dry season than before, which may have contributed to the apparent increase in the range and abundance of quelea in the Eastern Cape (Chapter 3). There is no evidence of this from ringing recoveries, but this is not surprising considering the complete absence of control operations, the most fruitful source of recoveries, in this region.

Subsequent development of more intensive agriculture in parts of the Eastern Cape appears to have created suitable winter grounds for quelea allowing them to remain in the same area long after natural food supplies would have been depleted. Although most quelea in this region may still move north to breed, it appears that agricultural changes which made conditions on the central plateau suitable for breeding in the 1950s, are now occurring in this region. Similarly, quelea appear to have adapted to the development of more intensive agriculture in areas of KwaZulu-Natal, where populations are thought to have increased by one to two orders of magnitude since the 1970s, and appear to have become more sedentary (Berruti 1995; Berruti 2000).

Understanding what influences quelea movement patterns is crucial to predicting periods of quelea damage and for the development of appropriate strategies for managing problem flocks. The aim of this chapter was to test the validity of claims that reliable, year-round, artificial food supplies provided by recent changes in agriculture in the Eastern Cape have allowed quelea to become more sedentary in this region. While large-scale movements still occur, the timing and extent of these movements in the Eastern Cape in recent years, as monitored by monthly census counts and ringing results, was hypothesised to be less dependant on local fluctuations in natural food supplies than was previously proposed. Consistent retraps of ringed birds throughout the rainy season (Elliott 1998) and evidence of local breeding were considered strong support for a resident population, while retraps/recoveries outside of the Eastern Cape may support existing models of quelea movements.

4.2 MATERIALS AND METHODS

4.2.1 Monthly estimates of granivorous birds utilising ostrich feedlots.

Numbers of granivorous birds utilising the ostrich feedlots at Brandeston, Riverside Farm and Katkop were estimated monthly by walking and driving fixed transects through the feedlots (Feare 1975). Birds sheltering in trees were flushed to allow them to be counted. Each transect took approximately 40 minutes at Katkop, 60 minutes at Brandeston and 90 minutes at Riverside Farm. Counts were made during the main feeding periods, early morning and late afternoon, at all three sites, and an additional midday count was included at Brandeston and Katkop. Since the main aim of the study was to determine the number of birds utilising the feedlots, estimates were generally confined to birds flying, feeding, or roosting within the feedlots at each site. Because of the small size of the Katkop ostrich feedlot, additional counts were made in the surrounding fields. No visits were made to Riverside Farm in August 1997 and to Katkop in August and December 1997.

For all species other than quelea it was usually possible to count individual birds and their positions were marked on a map of the feedlot. Small flocks of quelea, fewer than 100 birds, were relatively easy to count or estimate. Tests showed that after some practice, flocks of up to 500 birds, particularly common in winter, could be estimated relatively accurately. These large flocks were estimated when birds landed on fences or as they arrived in a steady stream at the feedlots and groups of approximately 50 to 100 birds could be distinguished. Estimates were checked by photographing flocks and later counting the numbers of birds in each (Murton *et al.* 1972; Inglis *et al.* 1990). Comparisons of field estimates with photographic counts of the same flocks showed that flocks of 10-100 quelea were estimated with an error of approximately 10%, while flocks of 100-500 birds were estimated with about a 20% error. Larger flocks were generally divided into smaller units and thus an error of about 20% would also be expected. Most estimates were lower than the true value but no attempt was made to correct the daily counts.

It was unlikely that all birds of all species utilising the feedlots were present during any one count (Murton *et al.* 1963; Feare 1975), consequently the maximum count for the day was used as the best estimate of bird numbers (Murton *et al.* 1972), rather than a mean. Variability between days is also an important factor to consider since not all birds are likely to feed in the same area each day. During longer visits to the Riverside Farm ostrich feedlot in December 1998 and January, April and May 1999, transect counts were made on additional days to assess day-to-day changes in the number of granivorous birds using the feedlots.

Because of the mobility of birds and the length of time taken to travel the transect it is likely that some birds may have been counted more than once, while others were missed due to their feeding in long vegetation, sheltering in trees, or moving into areas which had already been counted. Since birds were moving both into and out of areas already counted, double counts and missed birds were assumed to have cancelled each other out (Feare 1975). Birds hidden in vegetation could not however, be compensated for and thus counts were likely to underestimate actual bird numbers.

Quelea flocks frequently contained other species such as Masked Weavers and sparrows. It was usually not possible to count different species separately, but when part of the flock was counted this was extrapolated to the rest (Toor *et al.* 1986). Cape Sparrows *Passer melanurus* and Grey-headed Sparrows *Passer griseus* at Brandeston usually occurred in mixed flocks and as they could not be readily distinguished in flight, estimates were combined.

4.2.2 Ringing.

An intensive ringing program was initiated in 1997 to determine longer term local movements of birds as well as to contribute to our knowledge of migration patterns within the Eastern Cape. Initially trapping was confined to the immediate vicinity of the ostrich feedlot at each site (Katkop, Riverside Farm and Brandeston), but was later expanded to include alternative food sources and other nearby farms (Lowlands Estate neighbouring Katkop in the Fish River area and Resolution Hatchery neighbouring Brandeston in the Fort Brown area). Although granivorous birds, particularly quelea, were being specifically targeted, all species captured during the trapping sessions were banded with individually numbered metal SAFRING rings. Birds were captured using mist nets set up in feeding areas, secondary (day) roosts, pre-roost gathering areas and along frequently used flight paths. Trapping effort varied considerably between sites and visits depending on the duration of the visit, the weather, the numbers and behaviour of birds (dispersed or concentrated) and the availability of helpers.

Primary and secondary wing moult was scored for each bird and the presence or absence of tail, body and head moult and various plumage characteristics were recorded. Wing length (maximum chord) was measured with a standard wing rule and mass was measured with a Pesola spring-balance to the nearest 0.5 g. Where large numbers of quelea were handled, random samples of birds were measured while the remainder were simply ringed and released.

4.2.3 Observations of quelea daily movement patterns and roost sites.

Movement patterns of quelea at the ostrich feedlots were recorded during transect counts and additional observation periods to determine important feeding and drinking sites, and the location of secondary roosts and pre-roost gathering areas. An effort was also made to locate night roosts by observing the departure direction of quelea flocks from the feedlots at dusk and the directions from which they arrived in the morning for several successive days. These observations were supplemented by extensive searches of the reed beds and thorn trees along the farm boundaries.

4.2.4 Breeding.

In an effort to locate breeding colonies, regular surveys of riverine vegetation and known secondary roosts were made at each site while birds were in breeding plumage. Records of local breeding and of juvenile quelea were obtained from farmers and the personal records of amateur birders, in particular W. Howe of Bedford, as well as from the South African Bird Atlas Project database and Diaz Diary, the newsletter of the Diaz Cross Bird Club.

4.3 RESULTS

4.3.1 Fluctuations in bird population sizes from transect counts.

Quelea were the most abundant species utilising the ostrich feedlots at both Riverside Farm and Katkop, while Cape and Grey-headed Sparrows combined, were the most abundant at Brandeston. Sparrow ringing data and population fluctuations were compared to that for quelea, because although they showed a similar seasonal pattern of high and low abundance to quelea at Riverside Farm, recapture rates were considerably higher for sparrows.

Riverside Farm.

Quelea numbers at Riverside Farm (Figure 4.1) remained at a fairly constant low level, approximately 3000 birds, between July and December 1997. There was, however, a marked increase over winter and spring (non-breeding season) in 1998, possibly as alternative food supplies, such as natural grasses, became more difficult to locate forcing birds to concentrate at the few remaining artificial food sources. This pattern appeared to be developing again in 1999 before transect counts were ended.

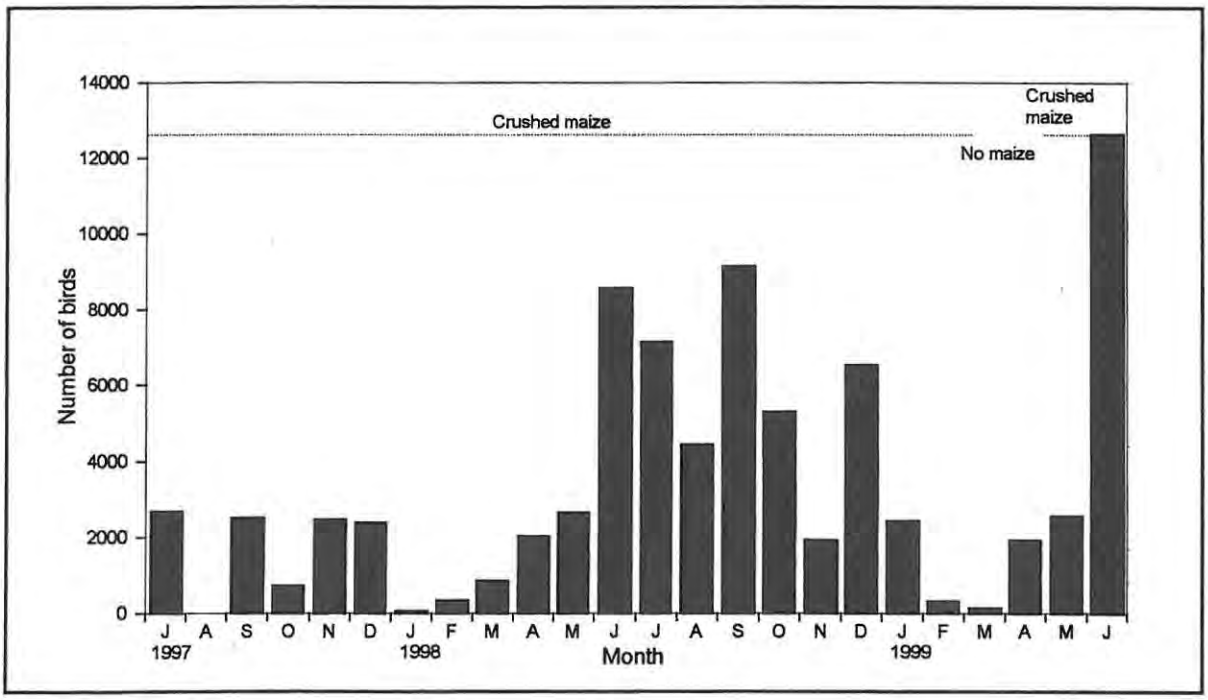


Figure 4.1 Estimated numbers of quelea at Riverside Farm between July 1997 and June 1999.

The relatively low numbers of quelea recorded in August 1998 may be attributed largely to the strong winds and resultant stinging dust clouds that were characteristic of the Riverside Farm feedlots at that time of year (A. Roets, pers. comm.). The dust not only forced birds to find cover, but also reduced visibility and made accurate counting very difficult. The attractiveness of ripening wheat in nearby fields probably accounts for the temporary drop in quelea numbers recorded at the feedlot in November 1998. Several large flocks of over one thousand birds were observed feeding in the wheat fields and roosting in *Acacia karroo* trees bordering the cultivated lands. Predictably, after the wheat was harvested in December the number of quelea at the feedlots increased once again. During January 1999 the amount of maize in the ostrich ration was halved due to economic considerations and, although quelea still fed at the feedlot, more than 2000 quelea (adults in breeding plumage) were seen feeding on grass seeds (mainly *Setaria* sp. and *Urochloa panicoides)* growing along the edges of fields and roads. A reduction in quelea numbers at the feedlot and a change to a more natural diet were expected over the main breeding period (January-March) in both 1998 and 1999.

Table 4.1 Day-to-day fluctuations in the number of quelea counted at Riverside Farm.

Month and year	Maximum daily estimate of quelea in the ostrich feedlot				
	Day 1	Day 2	Day 3	Day 4	Mean and standard deviation
December 1998	4481	5788			5135 ± 924
January 1999	1977	1515	2197	2428	2025 ± 386
April 1999	1381	1778			1580 ± 281
May 1999	2355	2455	2564		2458 ± 105
June 1999	12630	11982			12306 ± 458

Day-to-day changes (Table 4.1) in the maximum number of quelea estimated to be utilising the feedlot in December and January (summer), April and May (autumn) and June (winter) appear relatively low. In all cases the standard deviation for the estimates was below the 20% error expected for counts of large flocks of quelea. This suggests that the number of quelea utilising the feedlots was relatively stable, at least over short periods within a month and that differences between counts can be largely attributed to inaccuracies in the counting method. In winter and spring, when grass seed is scarce and quelea are most dependent on maize (Chapter 6), the number of birds utilising the feedlots would be expected to be at its greatest, though not necessarily stable.

Differences between months may be attributed to the immigration and emigration of birds in response to food availability in surrounding areas and/or changes in breeding condition.

Katkop and Lowlands Estate.

In contrast to Riverside Farm, the ostrich feedlot at Katkop was only one of several "attractive" (abundant crushed maize) food sources which included a nearby cattle feedlot, dairy, harvested maize lands together with ostrich and cattle feedlots (Plate 6) on the neighbouring farm, Lowlands Estate. Food suitable for quelea was available in the ostrich ration at Katkop for only the first ten months of the study. Consequently, changes in the number of quelea utilising the ostrich feedlot (Figure 4.2) are more likely to reflect changes in the relative attractiveness of alternative food sources, rather than more general fluctuations in the overall quelea population in the area. Indeed, birds ringed at this site were subsequently recaptured at more attractive feeding sites on Katkop and Lowlands Estate (Appendix 3).

Plate 6 Cattle feedlot at Lowlands Estate.

Thus, while it appears that quelea are most abundant at Katkop in summer and least abundant in winter, it should be noted that approximately 2000 quelea were present at the Katkop cattle feedlot during May and June 1998 and at the Lowlands Estate cattle and ostrich feedlots throughout the autumn and winter of 1998. Over 4000 quelea fed daily at the Katkop dairy alone during the winter of 1999. Therefore, rather than reflecting a general exodus of quelea from Katkop in winter, it appears that the decrease in the number of quelea feeding at the ostrich feedlot after early summer 1997-1998 (Figure 4.2) was the result of a reduction in the quantity (fewer ostriches) and quality (removal of all maize in April and May and introduction of whole maize into the ostrich ration from June 1998) of the food source.

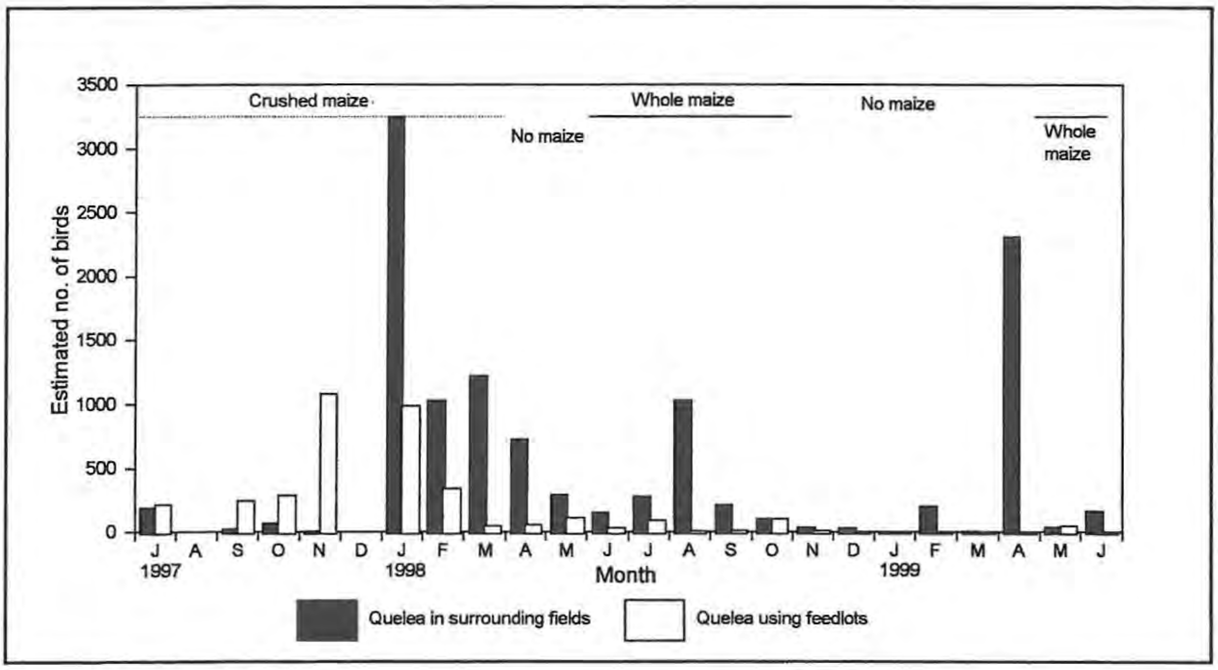


Figure 4.2 Estimated numbers of quelea at Katkop between July 1997 and June 1999. Birds in the feedlots and surrounding fields are plotted separately.

After the removal of crushed maize from the ostrich ration in April 1998, quelea numbers in the feedlot rarely exceeded 100 for the remainder of the study, and these were most likely attracted by the abundant weed growth. Apart from occasional periods of unusual abundance when large flocks of quelea were seen feeding in the surrounding lucerne lands (presumably on insects or fallen weed seeds), numbers in the fields around the study site also remained low. The decrease in quelea numbers at the ostrich feedlot after January 1998, prior to the removal of crushed maize, was mirrored by a more gradual reduction in numbers seen in the surrounding fields (Figure 4.2).

Such behaviour is to be expected at the start of the breeding season when new and abundant sources of natural grass seeds were again available.

Brandeston.

Sparrows at Brandeston (Figure 4.3) showed a pattern of population fluctuation similar to that of quelea at Riverside Farm. Highest numbers were recorded in autumn and winter 1998 and lowest numbers in summer during 1997-1998 and 1998-1999. The summer departure from the ostrich feedlot did not appear to be related to food availability since the cactus, *Cereus jamacaru*, produced abundant fruit between January and April that was readily eaten by sparrows (pers. obs.). Suitable nest sites were abundant and there was sufficient evidence (nest building, completed nests, parents carrying food and the appearance of numbers of juvenile birds in the population) that breeding took place within the pens from about November to March. The drop in numbers during spring and summer may be related to post-breeding dispersal. Unlike quelea at Katkop, the removal of crushed maize and subsequent changes in the ostrich ration at Brandeston did not appear to affect sparrow numbers. This suggests a much lower dependence on this food source than for quelea.

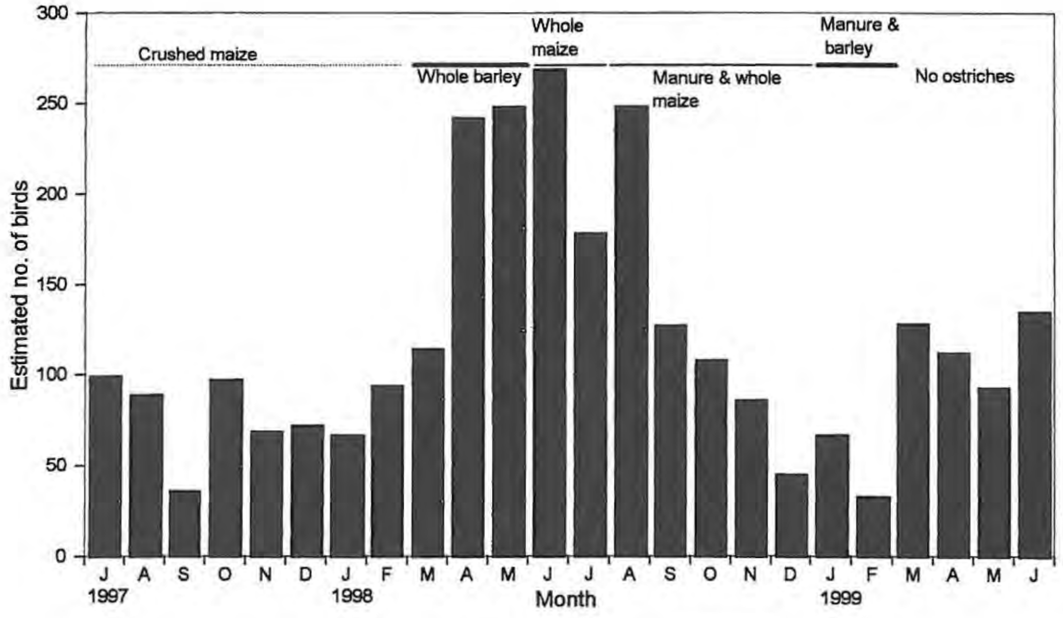


Figure 4.3 Estimated number of Cape and Grey-headed Sparrows at Brandeston between July 1997 and June 1999.

4.3.2 Ringing data.

Quelea.

As expected, the majority of quelea recaptures/recoveries at both Riverside Farm (60%) and Katkop/Lowlands Estate (97%) were between May and September, corresponding closely with the dry season for those areas (Table 4.2). Census data show that quelea tend to concentrate at reliable, artificial food sources such as feedlots over the dry season and it is not surprising that there are also good indications from ringing data that they may also be relatively sedentary over this period. Comparatively few quelea were recaptured/recovered between October and April when "early rains" and "breeding migrations" are believed to occur and when alternative natural food sources are more abundant. Recapture/recovery results for Katkop and Lowlands Estate are likely to have been strongly biased by the increased ringing effort on these farms in June and August 1999 and a measured ringing effort is recommended for future studies. The sedentariness of quelea at the feedlots, at least during the dry season, is nevertheless well illustrated.

Table 4.2 Number of quelea recaptured/recovered at Brandeston (B), Riverside Farm (RF), Katkop (K) and Lowlands Estate (LE) (1997-1999) in each month. Non-significant recoveries (i.e. 1-2 days after ringing) were excluded.

Farm	Number of birds recaptured each month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B										1		
RF	1	0	0	0	4	3	0	0	2	4	0	1
K/LE	0	0	0	0	2	17	2	20	0	2	0	0

Katkop and Lowlands Estate.

In total, 2392 quelea were ringed at Katkop and Lowlands Estate between July 1997 and August 1999. Sixty of these were recaptured/recovered (excluding only those birds recaptured where they were ringed on the same day that they were ringed), two of them twice on different days. The overall recapture/recovery rate for quelea ringed in the Fish River area was 2.5%.

Time intervals between ringing and recapture of quelea in the Fish River area varied from the same day to 19 months (Figure 4.4). As would be expected, the majority of recaptures (52%, even excluding repeat recaptures and those of less than one day) were made within one month of ringing (Appendix 3). The high proportion of recaptures at around three months is an artifact of uneven netting effort. Approximately 700 quelea were ringed in June 1999 alone and many of these were recaptured on the subsequent trip in August 1999.

Three quelea ringed in the Fish River area (AD51410; AF24310; AF37962) were recaptured after one breeding season and a further four (AE65204; AF00058; AF37930; AF75947) were recaptured more than one year after being ringed (Appendix 3). Despite this, evidence of local breeding remains circumstantial (Chapter 5), and the existence of a resident quelea population unproven. Long-term recapture/recovery data do, however, demonstrate that the Fish River area serves as a regular dry season refuge for quelea and that individuals may overwinter in the same areas in consecutive years.

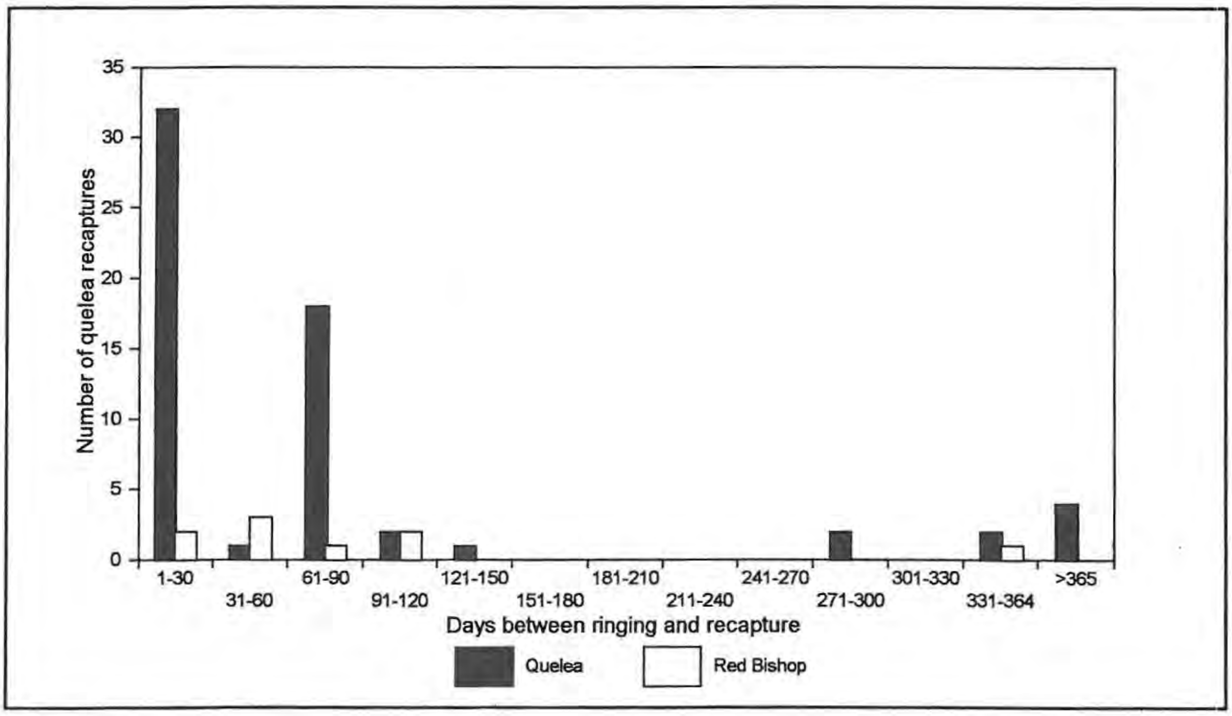


Figure 4.4 Time interval between ringing and recapture/recovery of quelea and Red Bishops ringed at Katkop and Lowlands Estate between July 1997 and August 1999 (recaptures < 1 day have been excluded).

Quelea also show a high degree of faithfulness to reliable foraging areas and 43 (72% of recaptures) birds were recaptured where they were feeding when they were first ringed (Table 4.3). All but one of these was at the Katkop dairy and this is probably due to the increased netting effort at this site between May and August 1999. Of the remaining recaptured/recovered quelea, 19 were recaptured at alternative food sources within 3 km of where they were ringed (Table 4.3). Two quelea, AF37930 (ringed at Lowlands Estate) and AF75947 (ringed at Katkop Dairy), were recovered in an ostrich feedlot on the farm Soutpansdrift (31°39' S; 25°29' E) approximately 26 km from where they were ringed 410 and 478 days later respectively. Trapping was, however, confined to Katkop and Lowlands Estate and therefore any movements of quelea further afield were very much less likely to have been detected.

Changes in foraging area were largely attributable to a subsequent reduction in the quantity or quality of the food available to birds at the site where they were first ringed. The movement of eight quelea from the Katkop dairy to the feedlots on Lowlands Estate could not, however, be explained in this manner. Indeed two of these birds (AF85942; AF85995) were recaptured at the Lowlands Estate ostrich feedlot only hours after being captured and ringed at the Katkop dairy (1.3 km away). Thus even within one day, in the absence of any apparent changes in the quality or quantity of the food available at the dairy and while large numbers of quelea continued to feed there, two quelea changed foraging areas.

Table 4.3 Movement patterns of quelea and Red Bishops (given in parenthesis) ringed at Katkop and Lowlands Estate between July 1997 and August 1999. Birds recaptured on the same day at the same site were not included.

Ringing site	Recapture site					
	Katkop ostrich feedlot	Katkop maize lands	Katkop cattle feedlot	Lowlands Estate cattle & ostrich feedlot	Katkop Dairy	Soutpansdrift ostrich feedlot
Katkop ostrich feedlot		1	3		2	
Katkop maize lands						
Katkop cattle feedlot		2		1	1 (2)	
Lowlands Estate cattle & ostrich feedlot	(1)			1	1 (3)	1
Katkop Dairy				8	42 (3)	1

In most cases, movements of ringed birds from one site to another may be attributed to general foraging movements of the local quelea population. Two examples however, appear to be more than just coincidence, and suggest at least limited group cohesion. Queleas AF24016 (adult male) and AF24017 (suspected juvenile) were ringed together at the Katkop ostrich feedlot in February 1998 and were both recaptured at the Katkop cattle feedlot in June the same year, although on different days. Similarly, quelea AF24206 was ringed at the Katkop cattle feedlot on the same day as quelea AD51410 was recaptured there. When recaptured together the following month, both birds were foraging in a nearby maize field.

Excluding same day recaptures, only two quelea were recaptured more than once. The first individual (AD51410) was ringed at the Katkop ostrich feedlot in September 1997 and was recaptured initially at the Katkop cattle feedlot in June 1998 and then in a maize field near the ostrich feedlots the following month. The second (AF50743) was ringed in May 1999 near the Katkop ostrich feedlot and was recaptured on two consecutive days the following month at the Katkop dairy.

Riverside Farm.

Due to the lower number of quelea ringed at Riverside Farm (2065) and the greater overall abundance of quelea, the lower recapture/recovery success, 21 birds (1.0%), is not surprising. This does not necessarily suggest a more nomadic or migratory population than in the Fish River area.

The longest recorded distance travelled by a quelea ringed in the Cookhouse area was approximately 465 km in a northwesterly direction. The adult male quelea (AF37832) travelled from the Riverside Farm ostrich feedlot where it was ringed in October 1998 to Jacobsdal (29°09' S; 24°46' E) (Appendix 2) where it was recovered 376 days later in November 1999. This quelea had almost completed moult of secondary wing feathers and was entering breeding plumage when it was ringed. Its recovery in the Free State Province of South Africa provides a good indication that quelea from the Eastern Cape may well undertake a breeding migration.

Only two other quelea ringed at Riverside Farm were recaptured away from where they were ringed, although still on the same farm. These quelea (AF50261 and AF50305) were ringed on the same day in April 1999 at the Riverside Farm ostrich chick pens and were recaptured 71 and 29 days later respectively, approximately 1 km away at the main ostrich feedlot.

The remaining 18 recaptures were all made within several hundred metres of where the quelea were ringed. This may give the misleading impression that birds were more restricted in their feeding movements at Riverside Farm than at Katkop and Lowlands Estate. However, the pens (many of them empty) that comprised the main feedlot at Riverside Farm were spread out over almost 2 km (Plate 7). Furthermore, the location and amount of food available varied depending on the distribution of ostriches and on the number of ostriches in each pen. Thus, movements within this complex can easily be equated to those between sites at Katkop and Lowlands Estate. Recoveries of birds stupefied with alpha-chloralose (Chapter 7) show that considerable movement occurs over this area, despite the apparent abundance of food in each occupied pen. Although evidence from stupefied birds should be viewed with caution, as alpha-chloralose may have induced atypical behaviour, observations of untreated flocks supported these findings.

Plate 7 Main feedlot at Riverside Farm with empty pens in the foreground and occupied pens in the distance.

As expected, even when same day retraps were excluded, a large proportion (48%) of the 21 recaptures/recoveries were made within the first one to two months after ringing (Figure 4.5). The proportion of medium and long-term recaptures was, however, greater than at Katkop and Lowlands Estate and this may be a consequence of the more consistent ringing effort at Riverside Farm. Five birds were recaptured within one to two days of ringing and this again points to a degree of faithfulness to particular feeding areas, at least over the short-term.

Nine recaptures/recoveries were over at least one breeding season (Appendix 3) and it is possible that at least some of these quelea departed the farm to breed, as is suspected of the individual recovered in Jacobsdal. Six recaptures were longer than one year and two of these were over two breeding seasons, the longest being 682 days. One quelea (AF24251) was ringed and recaptured exactly 365 days later in the Riverside Farm ostrich feedlot. As in the Fish River area, long-term recaptures/recoveries suggest that the Cookhouse area serves as a regular dry season refuge for quelea, and that at least some individuals are relatively sedentary or at least regularly return to the feedlot to overwinter.

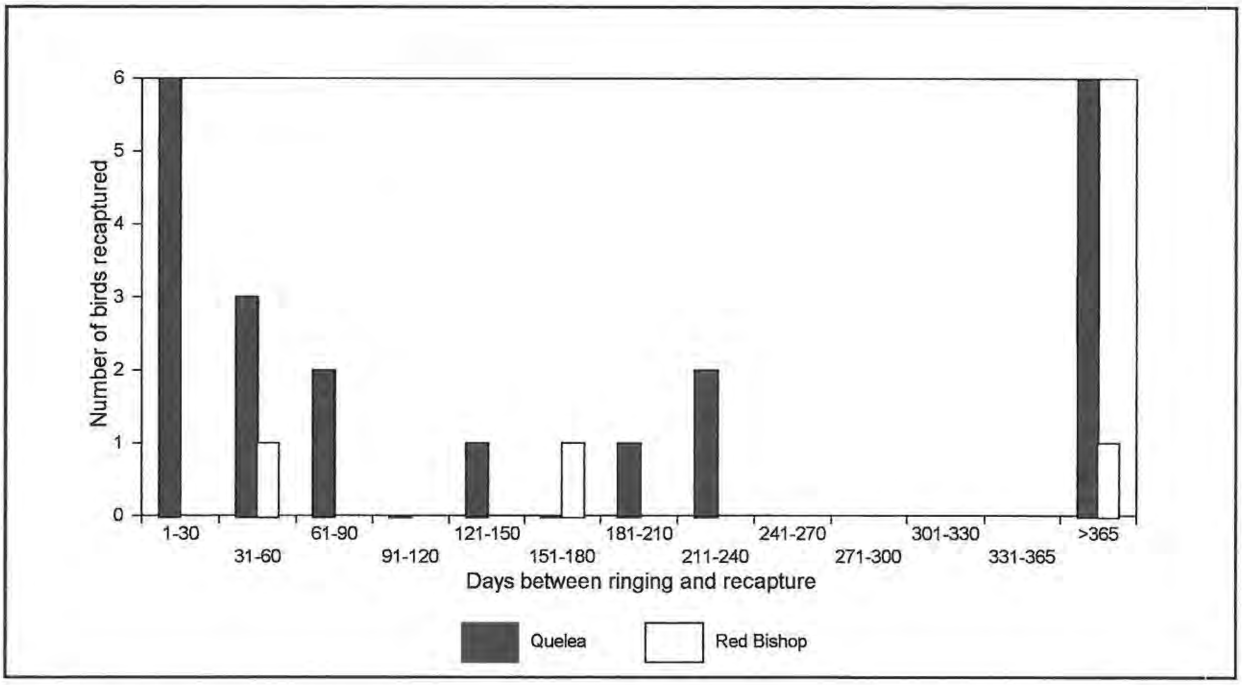


Figure 4.5 Number and interval between ringing and recapture of quelea and Red Bishops recaptured at Riverside Farm between July 1997 and June 1999. Recaptures of less than one day have been excluded.

The only direct indication that quelea may migrate along the Great Fish River was the sighting in late January 1999 of small flocks of quelea (20-300 individuals) moving down the river past Riverside Farm at dusk. The poor light made it impossible to determine whether the quelea were adults in breeding plumage or juveniles, but only adults had been observed along that stretch of river during the day. Flocks began arriving from upstream of the farm in late afternoon (18h30) and after briefly joining birds in the local "breeding colony", they continued downstream, flying low over the water. Within an hour, several thousand quelea (approximately 3000 in 20 minutes) had passed and the reed bed was deserted, the local birds presumably having joined the other flocks.

Brandeston.

Only one ringed quelea (AE65215) was recaptured on the farm Brandeston in the Fort Brown area. The quelea recapture rate for Brandeston was nevertheless still relatively high (0.8%) although only 121 quelea were ringed there between 1997 and 1999. The recaptured individual was ringed in August 1997 and recaptured at the same feedlot 74 days later in November (Appendix 3), again suggesting at least short-term faithfulness to reliable feeding areas. After February 1998 crushed maize was removed from the ostrich ration and quelea were only sporadically observed at the Brandeston feedlot over the remainder of the study.

Quelea were rarely seen at Resolution Hatchery and although a few were caught, no ringed quelea were observed there between April and June 1999. The last quelea were ringed at Brandeston in May 1999, but with the low number of ringed quelea in the Fort Brown area as a whole, detection of any movements between nearby farms was unlikely.

Red Bishops.

Since Red Bishops frequently move in flocks with quelea during the non-breeding season, the recapture of ringed bishops may indirectly contribute to our knowledge of the movements of quelea. Of the three ringed Red Bishops recaptured at Riverside Farm, one was recaptured where it was ringed (at the chick pens) only a month later. Another, also ringed at the chick pens, was recaptured 168 days later in the main feedlot. In both cases these recaptures merely confirm patterns already shown by quelea recaptures. The third, a male Red Bishop recaptured at the main ostrich feedlot in February 1998, was initially ringed at Eastpoort Bridge (approximately 12.5 km away, but still on the Great Fish River) 657 days previously in May 1996. Had it followed the bends in the river, the distance travelled would have been approximately twice as far. Small numbers of quelea and bishops were also ringed further upstream on the farm Celva, but no recoveries were ever made. Nine (4.5%) ringed Red Bishops were recaptured at Katkop and Lowlands Estate and these birds again showed very similar movements to quelea (Table 4.3 and Figure 4.4).

Sparrows.

The total numbers of Cape and Grey-headed Sparrows ringed at Brandeston over the study period (111 and 115 respectively) were remarkably similar as were recaptures of these species (9.0% and 7.0% respectively). Although many sparrows also appeared to depart from the feedlot in early summer, the recapture rate was much higher than for quelea. Four birds ringed before the summer dispersal (January-February) were recaptured after sparrow numbers began to increase again in late summer and early autumn. As with quelea, this suggests that these sparrows either did not leave the feedlot or that at least certain individuals have a tendency to return to familiar areas during winter. The remaining 13 recaptures were either sparrows ringed and recaptured before the summer exodus, or were birds that were ringed in summer and recaptured later that same year.

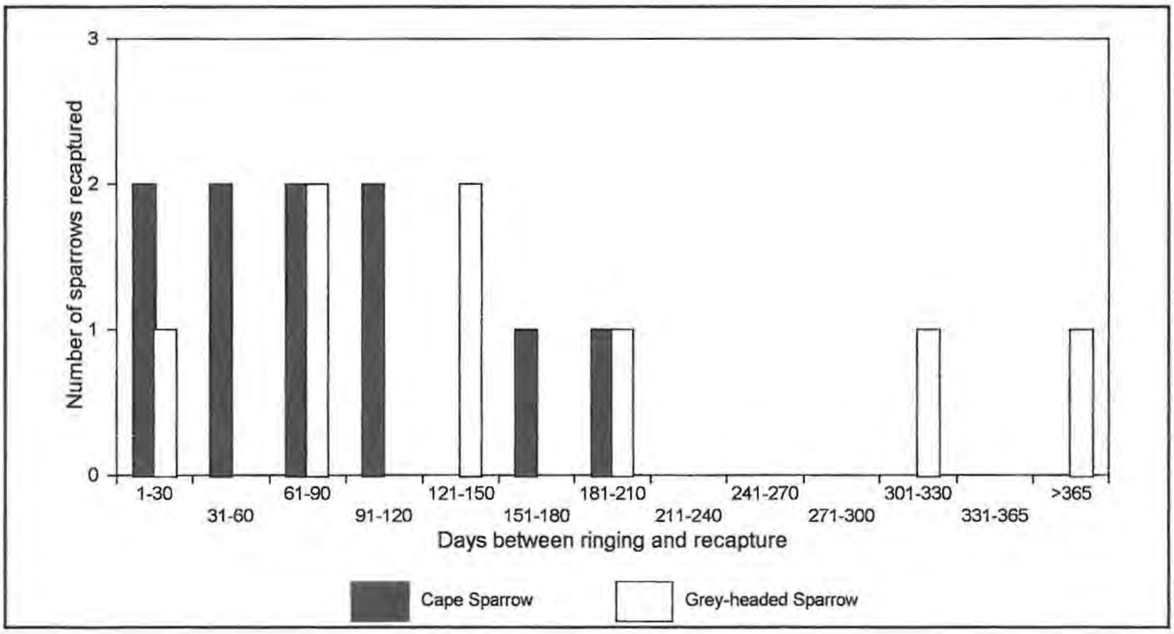


Figure 4.6 Numbers and interval between ringing and recapture of Cape and Grey-headed Sparrows recaptured at Brandeston between July 1997 and June 1999.

Recaptures of ringed birds also provide evidence for group cohesion amongst Cape Sparrows, since on two occasions two birds ringed on the same day were recaptured together 57 and 113 days later respectively. Only one sparrow was recaptured more than one year after ringing and the three longest periods between ringing and recapture, 204, 303 and 380 days (the latter two were the same bird), were all for Grey-headed Sparrows (Figure 4.6).

4.3.3 Feeding behaviour.

Feeding flocks of quelea varied considerably in size from less than 100 to over 1000 individuals. These were never static and smaller groups continuously joined and separated from the main flocks as they moved about the feedlot. Though frequently flying for cover when a raptor or pigeon passed overhead, they would also rush to nearby trees without any obvious sign of danger. The majority of quelea fed in the open ostrich pens picking up spilt maize, scratching through the lucerne and maize mixture, or feeding on grass and weed seeds. Small flocks were also frequently seen feeding in a large shed at Riverside Farm (pers. obs.), and some of these quelea may even roost there on occasion (A. Roets, pers. comm.).

4.3.4 Secondary (day) roosts.

Secondary roost sites were easily located by loud singing and the frequent arrival and departure of small flocks of quelea throughout the morning and early afternoon. There were often several main roosts in use at any one time and these were usually located in reeds or patches of *Acacia karroo* near water (Great Fish River, earth dams or irrigation canals) where the birds could drink. Secondary roosts were very dynamic and while some were used for several months at a time, others were abandoned and then later reoccupied. This may have been related to the location of popular feeding sites. Practice nests were built at all times of year by birds in both breeding and in non-breeding plumage.

4.3.5 Pre-roosting assembly areas and primary (night) roosts.

Although several patches of trees at Riverside Farm appeared to serve as assembly areas for birds at the feedlot, not all birds were attracted to them. Of those that were, not all remained there until the main flock departed to roost, but rather returned to feed or left the area in smaller flocks. Some birds continued to feed throughout the late afternoon and eventually departed the feedlot at dusk, apparently without first having attended a nearby assembly area. No night roosts were located at either Riverside Farm or Katkop/Lowlands Estate, despite extensive searches along the river bordering these farms. Flocks of birds (20-100) arrived just after dawn and departed again at dusk in several directions, suggesting more than one primary roost. Flocks tracked on foot across the veld at Riverside Farm for several evenings were still flying high and fast at the farm boundary (more than two kilometres from the feedlots), which suggests that the roost was still some distance away.

4.3.6 Breeding.

A breeding colony of several thousand quelea was discovered in an approximately 100 m long stretch of reeds along the Great Fish River at Riverside Farm on 28 January 1999. The natural grasses had begun to set seed following the spring rains, nests were in various stages of completion and both male and female quelea were in full nuptial plumage. Samples of birds collected at the feedlot during this period indicated that all males had enlarged gonads and some females had large yellow yolks (±10 mm), indicating that laying was imminent. However, by 17 February the colony had been abandoned, possibly due to the reduction of crushed maize in the ostrich ration during that month, without any evidence of eggs having been laid (i.e. no shells or dead chicks). Despite this, juvenile quelea less than two months old (Chapter 5) were caught at the Riverside Farm feedlots in mid February 1999, suggesting that breeding had indeed taken place somewhere nearby.

No active quelea breeding colonies were discovered in the Fish River area in 1998 or 1999. However, females with yellow bills (i.e. having completed pre-nuptial moult) were present at Katkop and Lowlands Estate in both years and juveniles less than two months old (Chapter 5) were subsequently trapped at the dairy in 1999. Furthermore, the high proportion of insects in the diet of adult quelea caught in the Fish River area over summer 1998-1999 are consistent with quelea feeding nestlings (Chapter 6). It is therefore possible that local breeding took place undetected, especially when one considers that some of the oldest records of quelea breeding in the Eastern Cape are from well south of this area along the Great Fish River (James 1921). Additional quelea breeding records for Cradock, Cookhouse and the nearby Bedford area are shown in Table 4.4. Most of these records were collected by W. Howe and although many only indicate suspected breeding, they do suggest that birds in breeding condition are not unusual in these areas.

In most cases, these records do not indicate the exact day on which the observations were made nor the stage of breeding (e.g. eggs, chicks etc.) and thus the date on which breeding commenced cannot be determined. The earliest month for which breeding has been confirmed in the Eastern Cape is November and the latest is May. Three records of confirmed breeding are for spring (September-November), six records are for summer (December-March) and six records are for autumn (April-May). Predictably, no breeding took place in winter. The November records were most likely for eggs in the nest while those for May would be expected to be for fledglings or independent juveniles.

Table 4.4 Records of confirmed and suspected quelea breeding in the Cradock, Cookhouse and Bedford areas. Data are presented in chronological order and include records from published literature, the South African Bird Atlas Project (SABAP), the Nest Record Card Scheme and private notes. Names in italics indicate farms.

Location	Month (Day)	Year	Source	Confirmed Breeding (B) and stage if known Suspected Breeding (SB)
Halesowen (Cradock)	4	1910	H. James (1921)	B
Cradock (8 miles north)		1920	H. James (1921)	B
Mortimer (Cradock)		1920	H. James (1921)	B
Cradock	4 (5)	1921	Nest record card scheme	B (eggs)
Cradock	11 (24)	1926	Nest record card scheme	B (eggs)
Cradock	4 (1)	1928	Nest record card scheme	B (eggs)
Cradock	2	1987	SABAP	SB
Fish River rail siding	12	1987	SABAP	B
Cookhouse	11	1989	SABAP	SB
Cookhouse	12	1989	SABAP	SB
Bedford *Malangskraal*	2	1993	W. Howe (pers. records)	B
Cookhouse *Celva*	12	1994	W. Howe (pers. records)	B
Cookhouse *Ripplemead*	12	1994	W. Howe (pers. records)	SB
Cookhouse *Bulkraal*	1	1995	W. Howe (pers. records)	B
Cookhouse *Renfield*	1	1995	W. Howe (pers. records)	SB
Bedford *Kingsvale*	3	1995	W. Howe (pers. records)	B
Bedford *Malangskraal*	3	1995	W. Howe (pers. records)	B
Cookhouse *Celva*	3	1995	W. Howe (pers. records)	SB
Cookhouse *Wienandskraal*	11	1996	W. Howe (Diaz Diary)	B
Cookhouse *Sunkist*	4	1996	W. Howe (pers. records)	SB
Cookhouse *Wienandskraal*	11	1996	W. Howe (Diaz Diary)	B
Bedford *Malangskraal*	4	1997	W. Howe (Diaz Diary)	B
Bedford *Elizabeth Farm*	5	1997	W. Howe (Diaz Diary)	B
Bedford *Malangskraal*	11	1997	W. Howe (Diaz Diary)	SB
Cookhouse *Wienandskraal*	1	1998	W. Howe (Diaz Diary)	SB
Cookhouse *Slachtersnek*	5	1998	W. Howe (Diaz Diary)	B

4.4 DISCUSSION

At the end of the breeding season quelea initiate complete post-nuptial moult (Elliott 1990) and disperse from the breeding areas in search of food (Lourens 1963). Apart from the possible added energetic costs of this process (King 1980), wing moult may increase the costs of flight (Ginn & Melville 1983; Hedenström 1998) and both of these factors would be expected to limit bird movements over this period (Craig & Hulley 1994). However, as the dry season progresses, local food shortages may become acute, forcing quelea flocks ever further south (Lourens 1963; Jones 1989b). Quelea may become more sedentary in areas where food supplies are abundant throughout the dry season, and as flocks are attracted from surrounding areas where food supplies are depleted, local populations grow (Jones 1989a). Such behaviour is consistent with the observed increases in the size of the over-wintering quelea population at livestock feedlots in the Eastern Cape. The importance of such artificial food sources to quelea in the dry season is well known (Jarvis & Vernon 1989a; Berruti 1995).

In the same way that quelea may return to traditional breeding areas year after year (Jones *et al.* 2000), seasonal movements back to dry season refuges known to provide reliable, rainfall independent food supplies are clearly advantageous, and may explain long-term recaptures/recoveries of quelea ringed at Katkop/Lowlands Estate and Riverside Farm. The tendency of quelea to move along rivers (Lourens 1963) would increase the likelihood of individuals returning to the same farms along the Great Fish River in successive seasons and may help explain how group cohesion is maintained after long-distance migrations.

Quelea recapture/recovery rates for the Fish River (2.5%), Cookhouse (1.0%) and Fort Brown (0.8%) areas of the Eastern Cape Province were considerably higher than for South Africa as a whole. Including 'non-significant' recoveries (birds recaptured within a few days of ringing) and 16 recaptures of living birds by ringers, the overall quelea recovery rate for South Africa was just 0.38% by 1999 (Oschadleus 2000). This figure is approximately seven times lower than the recapture/recovery rate for Fish River, almost three times lower than for Cookhouse and half that for Fort Brown. While it is tempting to speculate that this points towards a more sedentary population in the Eastern Cape, there are vast differences in the overall scales of the national and localised (Fish River, Cookhouse and Fort Brown) quelea ringing and search efforts and in the sizes of the quelea populations being studied. This makes it difficult to draw any firm conclusions from comparison of recapture/recovery rates.

Although higher than the national figures, recapture/recovery rates for quelea in the Eastern Cape were nevertheless lower than expected given the estimated sizes of the quelea populations at the feedlots and the number of birds ringed. This may be at least partially explained by a steady influx of unmarked birds throughout the dry season and subsequent dispersal of birds in summer. Cape and Grey-headed Sparrows are also known to be nomadic in some areas at certain times of year (Tree 1972; Earlé 1988) and show a similar pattern of decreased abundance in summer followed by an increase in winter. Recapture success is likely to be inversely related to the total number of birds in an area, but will also be influenced by immigration and emigration rates. Relatively high recapture rates for sparrows at Brandeston therefore confirm estimates of a relatively small population (Appendix 4), but also suggest that local movements are more restricted than those of quelea at Riverside Farm and Katkop/Lowlands Estate.

The majority of Eastern Cape recaptures were short-term (about two months or less) and at best provide evidence of temporary fidelity to particular reliable feeding sites and do not necessarily demonstrate a shift in behaviour towards a more sedentary existence. Since most of the recaptures/recoveries were during the dry season when alternative food sources were scarce, concentration at reliable, artificial food sources such as feedlots is to be expected. Irrigated crops are thought to fulfil a similar function in other areas of South Africa, providing a reliable, artificial source of food that enables quelea to remain in areas for longer than would have been possible under more natural conditions (Oschadleus 2000).

The only other area of South Africa where quelea were ringed on a regular basis for several years was at Barberspan (26°35' S; 25°35'E) in the North West Province. Here too, quelea showed evidence of strong site fidelity with 181 recoveries after a control operation at Barberspan on 19 November 1975 (Oschadleus 2000). All these birds had been ringed within 4 km of the control site from 1 day to 3 years previously. While it is again tempting to speculate about a sedentary population, the recapture/recovery of a quelea ringed at Barberspan several hundred kilometres away in KwaZulu-Natal province 16 months later, demonstrates that this population also undertakes long distance movements. The many recoveries close to the ringing site therefore suggest that although quelea populations may be extremely mobile at certain times of year, some regularly return to suitable areas and may remain there for extended periods (Oschadleus 2000). Tree (1989) reported similar faithfulness to non-breeding sites among quelea in Zimbabwe, but also noted that they may overwinter thousands of kilometres away from where they were ringed the previous winter.

Recaptures/recoveries of quelea ringed in the Fish River area demonstrate that considerable movement occurs between feeding sites on the same farm (e.g. dairy to ostrich feedlots), between neighbouring farms (e.g. Katkop to Lowlands Estate and vice versa) and over a wider area (e.g. Katkop and Lowlands Estate to Soutpansdrift). The majority of these movements could be attributed to a reduction in the quality (e.g. crushed maize to whole maize or no maize) and/or the quantity of food available. Indeed, many individuals appeared to feed at the same site on consecutive days and even over several months provided that the food supply remained good. Others, however, behaved in a much less predictable manner and changed from the dairy to the Lowlands Estate feedlots for no apparent reason. Similar results were found in an intensive study of European Starling movements at livestock feedlots in the USA (Glahn *et al.* 1987). Only a small proportion of the population returned to feed at the feedlots each day, although most tagged birds remained faithful to the general area (Glahn *et al.* 1987). Furthermore, many European Starlings tagged while feeding at calf feedlots in Britain showed strong fidelity to preferred feeding areas, but they were also observed feeding away from the feedlot (Feare 1990).

It has been suggested that European Starlings exploiting feedlots in Britain still require insect food (Feare & McGinnity 1986, in Feare 1989) and thus while dominant birds return to feed at the feedlot each day, they also utilise the surrounding fields. The presence of both grass seeds and maize in the gut contents of quelea collected at the feedlots (Chapter 6) suggests that they may behave in a similar manner. Yet this does not explain why the same quelea would utilise a variety of different sources of crushed maize on the same day. Such behaviour may be related to competition at the primary feeding site, in this case the dairy. Feare (1990) found that dominant male European

Starlings out-competed females at feedlots in Britain while Glahn *et al.* (1987) found that residents were more likely to use feedlots than were winter visitors.

The mechanism for rapid information exchange is not clear from this study, but quelea are known to gather in secondary roosts during the midday period, where Ward and Zahavi (1973) suggest that they may "learn" of alternative food sites. Thus those birds that fed poorly at the dairy may follow a different flock to another more suitable site for the rest of the day and a similar principal may apply at primary roosts. The feedlot at Riverside Farm is very sparsely vegetated and visibility is good. It therefore likely to be easier for quelea to locate feeding flocks from some distance away, and they may be attracted to alternative sites by local enhancement (Ward & Zahavi 1973).

Several, apparently similar food sources (dairy, maize stubble and ostrich feedlot), may be exploited by different individuals in the local population at any one time. This "collective knowledge" of the quality of local food sources would greatly enhance the flexibility of the local population, and could serve as an insurance against the loss of an existing good feeding site. In a sense, the quelea population may continually assess the relative quality of various food sites, enabling them to respond rapidly to the availability of new food sources and the decline in quality of existing ones.

Quelea from a single roost may feed over a wide area (Ward 1965; Ward & Zahavi 1973; Allan 1996), but at the same time quelea exploiting a common feeding ground may frequent different primary roosts (Ward 1965; pers. obs). Similar behaviour has been recorded for the European Starling (Feare 1984) and the Dickcissel (Ffrench 1967). Given this and the inevitable mixing of flocks as they merge and split in the feeding areas, there appears to be a strong possibility that quelea may return to different roosts on successive evenings, despite the presence of pre-roost gathering areas. Although there is good evidence to suggest group fidelity among quelea during movements (Jaeger *et al.* 1989; Johns *et al.* 1989; Jones 1989b; Elliott 1990; this study), communal quelea roosts are considered dynamic and there may be a regular turnover of individuals (Ward 1979; Bruggers 1989). Similar behaviour has been recorded for other communally roosting species such as the European Starling (Thompson & Courlee 1963, in Ward & Zahavi 1973) and the Yellow-headed Blackbird *Xanthocephalus xanthocephalus* (Twedt *et al.* 1991). In this way, apparently erratic feeding patterns may perhaps be explained. Depending on where they roost and which foraging flock they join, some quelea may return to the same feeding sites daily giving the impression of a resident winter population, while others may feed many kilometres from where they were ringed, though still within the range of the local population. If this is indeed the case, a low recovery of ringed individuals is to be expected, especially in an area where relatively uniform farming practices provide numerous apparently similar feeding grounds (in this study Katkop, Lowlands Estate and Soutpansdrift each had feedlots where crushed maize was available). Indeed, Glahn *et al.* (1987) found that while the numbers of European Starlings observed at the study farm remained stable, the population turnover exceeded 70% between some months, although this was admittedly when migrants were present.

The arrival of the spring rains heralds the end of the dry season and causes most of the remaining grass and weed seeds to germinate (Ward 1965). As a result, for a period of several weeks until the new grasses and weeds set seed, quelea may be faced with a chronic food shortage (Ward 1971; Ward 1979). Under natural conditions in the early-rainfall areas such as the Eastern Cape, the only option available to quelea faced with a rapidly diminishing food source would have been to move to areas where rain had not yet fallen and dry grass seeds were still available. Although quelea may follow regular migration patterns and sometimes return to the same breeding or dry season areas (Jaeger *et al.* 1989; Jones 1989a; Jones 1989b; Elliott 1990; Jones *et al.* 2000), their movements are flexible and allow them to take full advantage of favourable conditions, while avoiding unsuitable areas (Elliott 1990). Thus in areas where rains are poor or scattered and sufficient seed remains ungerminated, quelea may not move at all (Allan 1996).

In a similar way, the provision of artificial food sources such as feedlots eliminates or at least reduces the urgency for quelea in early-rainfall areas to seek better foraging ahead of the advancing rain-front. The tendency of many quelea to remain at the feedlots long after nuptial moult had been completed may therefore be considered as an extension of their natural behaviour. By avoiding the energetically expensive movement away from the advancing rain-front and the "early-rains return migration" quelea are able to remain in their dry season refuge until new green seeds and insects become available in what then may be considered as their early-rains quarters.

Quelea require an abundance of green grass seeds and insects to feed their chicks (Lourens 1963; Ward 1971) and when conditions allow them to remain in their dry-season quarters until the new seed crop becomes available after the spring rains, one would expect them to breed nearby. Indeed, quelea are known to breed in their early-rains quarters if suitable conditions are available (Jones *et al.* 2000). Consequently, those quelea that have reached full breeding readiness when conditions are suitable may first breed where they over-wintered, before following other flocks on the northwards "breeding migration". Similar behaviour is known for the migratory Dickcissel that bred close to its wintering grounds when conditions permitted (Fretwell 1986).

Although no successful breeding colonies were located during this study, there is good circumstantial evidence to suggest that at least a small proportion of the over-wintering quelea population remains to breed in the Eastern Cape. Observations of adult quelea in full breeding plumage, nest building, enlarged reproductive organs, increased insect consumption (Chapter 6), the appearance of juvenile quelea with fresh plumage at the feedlots and adults with interrupted moult (Chapter 5) when taken individually do not provide conclusive support for claims of local breeding. But, when all these aspects are considered together, local breeding by at least a proportion of quelea at the ostrich feedlots seems highly probable.

A number of breeding records are available for the Cookhouse and nearby Bedford areas for the late 1980s and 1990s. Vegetation at Bedford, approximately 30 km from Riverside Farm, is described as False Eastern Cape Thornveld by Acocks (1975) and is typified by grasses such as *Setaria* and *Panicum* spp. which are considered vital to quelea breeding success (Ward 1971). Local breeding records are also available for other areas of the Eastern Cape and while part of the quelea population may indeed move north to breed, it is likely that at least some of the birds observed feeding at Riverside Farm through most of the year bred locally. This may be an alternative explanation for the several long-term, local quelea recaptures, which in other areas have been attributed to birds returning to the same site in subsequent years (Ward 1971; Jaeger *et al.* 1989). The two explanations are not, however, mutually exclusive.

Further evidence for local breeding was provided by the influx of juvenile quelea with fresh plumage into the Riverside Farm feedlot (chick pens) between mid-February and April 1999. These birds began their post-juvenile moult in mid-April and early May and if, as suggested, this begins about 9-13 weeks after hatching (GTZ 1987; Elliott & Lenton 1989) they may have come from a colony established somewhere between late December 1998 and mid-February 1999. January and February are considered to be the main breeding season for quelea breeding close to their early-rains quarters in northern South Africa and southern Mozambique (Ward 1971) and is consistent with the observations of nest building and breeding readiness. Although some juvenile quelea follow after their parents in the direction of the "breeding migration" (Jones 1989a), they generally appear to remain in their natal area for several weeks (Ward 1971; Jones 1989a), and attack crops close to the breeding colony (Ward 1973a).

Notwithstanding any local, short distance, summer dispersal of concentrated dry-season quelea flocks (to feed on replenished and widespread natural food sources) and evidence of local breeding, longer distance movements do occur. The dramatic reduction in the number of quelea observed at Riverside Farm over summer (1997-98 and 1998-99), the comparatively low number of quelea recaptures/recoveries from November to April at both Katkop/Lowlands Estate and Riverside Farm, the single long distance recovery in November, the influx of quelea, many with well-advanced primary moult (Chapter 5), at the Riverside Farm feedlot in June, and observations of interrupted moult in three quelea at Katkop (Chapter 5), thought to be an indication of a second breeding attempt (Elliott 1990), are commensurate with aspects of the existing model (Jones 1989b; Jones *et al.* 2000) of quelea migration in southern Africa. While there is no evidence to support an "early-rains return migration", this model's predictions of an exodus of quelea undertaking a "breeding migration" from the early-rainfall areas of South Africa (some time after the onset of the rainy season in this region in about October) (Jones 1989b; Jones *et al.* 2000) and a post-breeding dispersal whereby quelea return to their dry season refuges by late autumn or early winter (Jones 1989b), are supported. Rain fronts move from east to west across southern Africa between October and December (Oschadleus 2000) and the northwestward movement of quelea AF37832, recaptured at Jacobsdal in the Free State, is consistent with the model's prediction.

The explanation for differences in migratory tendencies among individual quelea over-wintering at feedlots is unclear, but is presumably related to differences in the fat reserves or general condition of individuals. Some of the more precocious quelea began pre-nuptial moult as early as August 1998 (Chapter 5) and thus may have approached reproductive readiness before local conditions were suitable for breeding. The possible departure of these precocious individuals early in the rainy season may have contributed to the population decrease at Riverside Farm after September 1998. Pre-migratory fattening within such a small proportion of the population would have gone unnoticed.

Similar reasoning may be used to explain why some individuals remained to breed locally in the Eastern Cape instead of, or before, joining the bulk of the local population on the northwards "breeding migration". Differences in migratory tendencies have also been recorded for European Starlings within the same population (Suthers 1978; Glahn *et al.* 1987), the same roost, the same brood and even the same individuals between years (Kessel 1953), but no explanations were suggested.

4.5 CONCLUSIONS

For the majority of quelea in areas of the Eastern Cape where large numbers of livestock are being fed, the availability of artificial food sources such as crushed maize may have reduced the extent of nomadic movements during the dry season and the urgency of the "early-rains migration". Indeed, many quelea appear to remain in their dry-season refuges until well after pre-nuptial moult is completed. While long distance "breeding migrations" do occur, albeit delayed in many cases, there is increasing evidence that at least some quelea attempt to breed within their dry-season refuges in the Eastern Cape after the spring rains. Consequently, while it is premature to consider quelea in the Eastern Cape to be resident, agricultural changes in the province in recent decades have allowed the timing and extent of quelea movements to become less dependent on natural cycles of food availability. Unless current trends in agriculture change dramatically, an increasingly sedentary component to the quelea population in the Eastern Cape is predicted.

MOULT, MORPHOLOGY AND PLUMAGE CHARACTERISTICS OF RED-BILLED QUELEA IN THE EASTERN CAPE PROVINCE

5.1 INTRODUCTION

Quelea undergo two moult cycles each year, a partial pre-nuptial moult into breeding plumage and a complete post-nuptial moult at the end of the breeding season. Although both aspects are routinely recorded as part of standard quelea monitoring (Allan 1996), little appears to have been published on post-nuptial moult (Thompson 1988). Moult is extremely important in the annual cycle of birds in terms of its energetic cost (King 1980) and the effect of moulting wing feathers on their flight capabilities (Hedenström 1998; Underhill 2000) and hence possibly on their movements.

It is hypothesised that two opposing forces might be expected to influence the duration of moult in quelea. The need to complete the energetically expensive moult process before the cold winter, when energy demands for thermoregulation are higher (Tinney 1997) and food availability is lower, would favour an early, rapid wing moult. In contrast, a later onset of moult and a slower replacement of flight feathers would appear necessary to limit disruption of flight capabilities during a period when quelea are dispersing long distances from breeding areas and later when dwindling, localised food sources necessitate that they remain highly mobile. The timing, duration and pattern of moult in quelea from the Eastern Cape are compared with data for other ploceids from the literature (Craig *et al.* 2001).

Breeding plumage of male quelea is highly variable, even within populations, and differences in the proportion of the various male morphs is one of the most important characteristics used to separate different races (Lourens 1963; Ward 1966; Allan 1996) and populations (Manikowski 1980). Consequently this aspect of moult has been comparatively well studied. Three races of quelea, *Quelea quelea quelea* (Linnaeus) of West Africa, *Quelea quelea aethiopica* (Sundevall) of Sudan and surrounding countries and *Quelea quelea lathamii* (Smith) of southern Africa have been accepted (Lourens

1963; Ward 1966; Allan 1996; Jones *et al.* in press). Clancey (1960) proposed a second, darker race *Quelea quelea spoliator* for southeastern Africa, but this was based on a small sample of 18 quelea in non-breeding plumage collected on the same day in the same location. Although Irwin (1989) believes "*spoliator*" justified following the examination of additional specimens (Clancey 1973), the sample still remains inadequate with only 107 quelea of both "types" from the whole of South Africa and just 410 specimens in total from throughout southern Africa. Small samples collected at various localities in Botswana showed highly variable mask indices and this emphasises the need for large representative samples (R. Allan, pers. comm.) and extreme caution when dealing with small ones.

Since genetic differences are likely to have arisen through geographic isolation of populations, it was hypothesised that if quelea in the Eastern Cape were indeed becoming more sedentary and thus separated, at least in terms of breeding, from more northern populations, then differences in plumage might be apparent (e.g. the ratio of the various male morphs in the reproductively isolated Eastern Cape population would be different to the ratio in populations elsewhere in the range of *lathamii*). Male breeding plumage was therefore recorded for the populations in the Cradock and Cookhouse areas and compared to published (Clancey 1973) and unpublished data for southern Africa (Lourens 1963; Allan 1994, unpublished data).

In addition, a proportion of quelea in non-breeding plumage, at least in the southern African populations, have a pink streak (varying in intensity between individuals) in the white eyebrow stripe (Plate 8). This characteristic, which has not been recorded in previous descriptions of *Quelea quelea lathamii* (e.g. Clancey 1960; Lourens 1963; Ward 1966; Clancey 1973), is not related to the age or sex of the bird since it may be present in juveniles and adults of both sexes. The proportion of individuals with pink in the eyebrow may provide a useful means of distinguishing quelea populations in non-breeding plumage.

Plate 8 Quelea in non-breeding plumage with a pink streak in the white eyebrow stripe.

5.2 MATERIALS & METHODS

5.2.1 Collection of birds.

Quelea for moult and morphological analysis were captured with mistnets at Brandeston, Riverside Farm and at Katkop and Lowlands Estate in the Eastern Cape between June 1997 and August 1999. A sample of birds killed in a chemical control operation was obtained from Villiers in the Free State (27°02'S; 28°37'E) in September 1999 for comparison. Juvenile quelea undergoing post-juvenile moult were separated from adults undergoing post-nuptial moult on the basis of differences in plumage and bill characteristics. Juvenile quelea were identified by their pale gape and buffy plumage, while adult male quelea frequently retained traces of their breeding masks until at least mid-moult. It became increasingly difficult to distinguish juveniles from adults towards the later stages of moult.

5.2.2 Scoring moult.

Primary and secondary moult was scored according to the method of Ginn & Melville (1983), where an old feather is assigned a value of 0 and a fully grown, new feather a value of 5. Thus a 9-primaried bird having completed primary moult has a primary moult score of 45. Wing feathers were considered new for one month after all individuals in the population had completed moult, but thereafter were scored as old until the following moult cycle was initiated. The presence of head, tail and body moult in quelea was also recorded.

5.2.3 Calculation of moult parameters.

The moult parameters (mean starting date, duration, and completion date of moult) were calculated using the model of Underhill and Zucchini (1988). In order to control for differences in the time taken to replace feathers of different sizes, this model uses moult scores converted to percentage feather mass grown. The model nevertheless still requires the less precise moult score data to assess the proportion of the feather grown.

As a comparison, duration of moult was also estimated from birds captured and marked in the early stages of moult and re-trapped towards the end of moult. Change in moult score and the approximate mass of feathers grown over time (Underhill & Joubert 1995, in Underhill & Underhill 1997) were used to estimate the rate of feather replacement, in terms of increase in moult score and unit mass grown per day respectively. Assuming a constant moult rate in individual birds, duration of moult was then calculated.

Newly replaced primary feathers, from three recently moulted quelea were plucked and weighed using an electronic balance (accurate to 0.001 mg) (Table 5.1). These data were then used to calculate the total mass of new primary feathers. As expected, the mass of feathers increased in ascending order from P1 to P9 (Table 5.1). The tenth primary is very reduced and was therefore ignored. There are six secondary feathers and three tertials that are sometimes treated together. For the purposes of moult analysis, quelea were considered to have nine primaries (P1-9) and nine secondaries (S1-9).

Table 5.1 Mean mass (mg) of freshly moulted primary feathers P1-P9 (n=3).

Primary no.	1	2	3	4	5	6	7	8	9	Total mass
Mean mass	6.7	7.5	7.6	8.3	9.5	10.2	10.3	11.4	12.5	84

5.2.4 Sequence of primary and secondary feather replacement in adult quelea.

To determine the sequence of primary and secondary wing feather replacement, the moult scores of each of the 18 wing feathers (P1-9 and S1-9) were individually summed for a random sample of 100 birds. The feather with the highest cumulative moult score was taken to have been shed first, the feather with second highest score to have been shed second and so on until the feather with the lowest score.

5.2.5 Moult as an indicator of age in juvenile quelea.

Too few moulting, juvenile quelea were caught at each site to reliably attempt to determine moult parameters for these birds. However, the primary moult score of birds undergoing post-juvenile moult can be used as an indicator of their age. This information can in turn be used to determine the timing of breeding attempts. Juvenile quelea were aged using a modification of the key developed by GTZ (1987). The original key related the approximate age of juvenile quelea to progression of moult. The extent of primary feather moult was scored according to the 4-phase method developed by Ward (1973b) and the key has been adapted here (Table 5.2) to enable the use of the 5-phase moult scoring method of Ginn and Melville (1983), which has been employed in the rest of this study.

Table 5.2 Key for aging juvenile quelea according to moult (modified from GTZ 1987).

Symptom	Age
Start of moult at head and back	55 days
Light moult of contour feathers all over the body	60 days
Heavy moult of contour feathers all over the body	70 days
1-2 points	80 days
3-5 points	85 days
6-10 points	91 days
11-15 points	101 days
16-20 points	110 days
21-25 points	125 days
26-30 points	143 days
31-35 points*	154 days*
36-40 points	165 days
41-45 points	up to 180 days

* The GTZ 1987 key omitted this category and an intermediate age of 154 days is therefore used.

5.2.6 Using plumage characteristics to distinguish isolated quelea populations.

Plumage characteristics of non-breeding (presence or absence of a pink streak in the eyebrow stripe) and breeding quelea (colour of male mask, presence/absence of pink wash around mask and or/on the chest and width of the frontal band) were recorded. Frontal band width was scored according to the method of Ward (1966), whereby the extent of band development was subjectively rated from 1-7 (Figure 5.1). This method was only suitable for dark-faced morphs, as the extent of the frontal band could not always be easily distinguished in white-faced individuals. Chi-squared tests for homogeneity were used to compare the proportions of different morphs in the various populations, for each plumage characteristic examined.

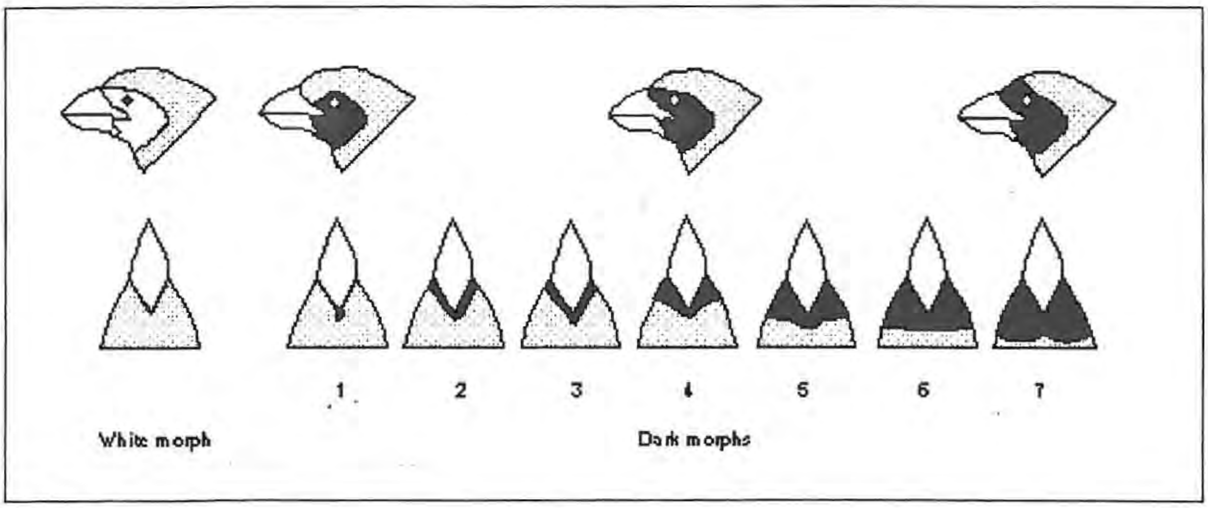


Figure 5.1 Classification of male quelea in breeding plumage according to width of the frontal band (from Ward 1966). Both the white-faced (russi) and dark-faced (mask) morphs are shown.

5.2.7 Measurement of morphological characteristics.

Wing length (maximum chord) was measured using a standard wing rule and birds were weighed to the nearest 0.5 g using a Pesola balance. Where catches were too large for all birds to be examined, random samples were measured and the remainder were ringed and released. The same measurements were made on birds killed for gut content analysis, but additional measurements of bill length (from tip of bill to union with skull), bill width and bill depth (across the nostrils) were also made to the nearest 0.1 mm using vernier callipers. Morphological characteristics were compared between sexes and sites using Multiple Analysis-of-Variance (MANOVA).

5.2.8 Transition from non-breeding to breeding condition.

Pre-nuptial moult in male quelea was divided into three stages according to the development of the breeding colouration, in particular the mask and surrounding areas. The stages were non-breeding plumage (individuals having completed post-nuptial moult but with no active pre-nuptial moult), transitional plumage (individuals with active head and/or body moult showing traces of a breeding mask either in the form of black/brown or pink speckling on the face, crown, head and/or chest) and nuptial plumage (individuals with fully completed breeding plumage). Intermediate stages of transitional plumage were not scored.

Transition of female quelea into breeding condition was monitored by recording changes in bill colouration. Once again the transition from non-breeding to breeding was divided into three stages, individuals in non-breeding condition had uniformly red bills, birds in the transitional stage had mottled red, orange or yellow bills and birds in breeding condition had uniformly yellow bills. Intermediate transitional stages were not scored, as the mottling did not appear to follow any particular pattern.

5.3 RESULTS

5.3.1 Post-nuptial moult parameters of quelea in the Eastern Cape.

Estimated start, completion and duration of primary moult using the Underhill-Zucchini model.

Post-nuptial moult began at the end of the breeding season (i.e. March/April) in the Eastern Cape population (Figure 5.2) with a mean starting date of 6 April (Day = 96; Standard error = 2) and a standard deviation of 36.5 days (Underhill-Zucchini model). Mean date for completion of primary moult was 8 August (Day = 220; Standard error = 1.4) with an estimated duration of 124 days (Underhill-Zucchini model). Primary wing moult was concentrated mainly in the period April to September (Table 5.3). At Riverside Farm the most precocious individuals completed wing moult in June of all three years, while at Katkop and Lowlands Estate quelea with completed moult were first recorded in July 1997 (no records were available for June 1997), August 1998 and June 1999.

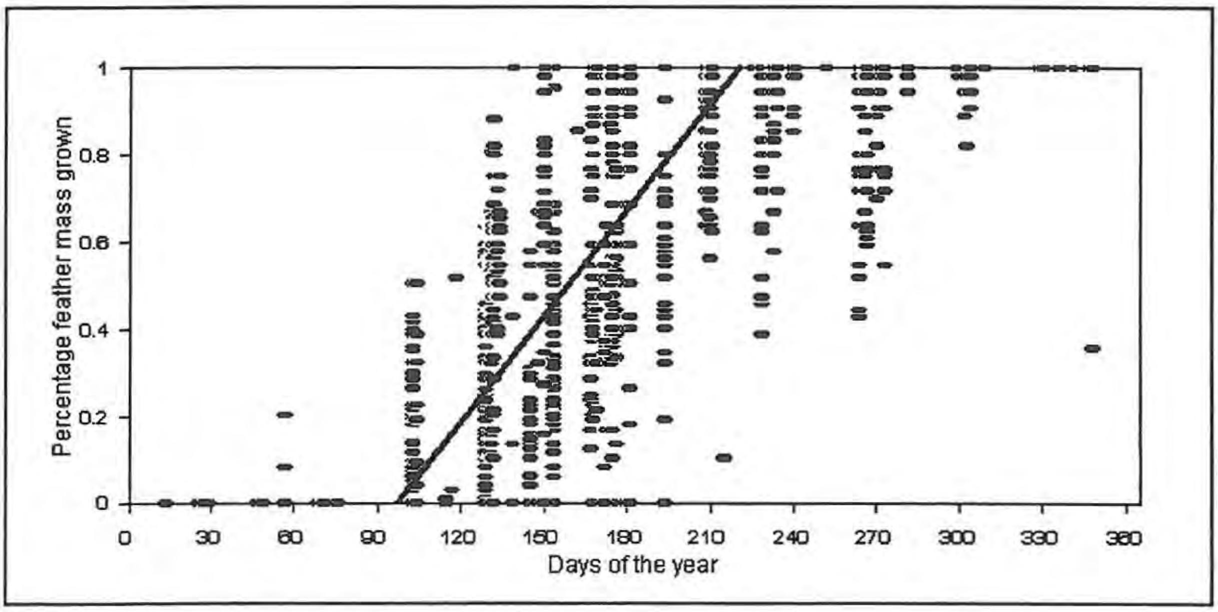


Figure 5.2 Primary moult indices for quelea in the Eastern Cape based on percentage feather mass grown. The solid line indicates the mean start and completion dates for moult calculated using the Underhill-Zucchini model and the average progression of primary wing moult in the population.

Table 5.3 The number of quelea captured in each month (n=3077), the percentage of birds with wing-moult, and the estimated duration (and standard error) of primary moult in days.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Duration
n	281	87	33	83	307	516	189	211	414	412	309	235	124 (±2.4)
%	0	2	0	58	92	95	95	29	22	4	0	0	

Estimated duration of primary moult using the mark-recapture method.

Using change in the primary moult score over time to assess moult duration, a wing moult period of 103 days was estimated for a quelea (AD51410) trapped with a primary moult score of 16 and recaptured 57 days later with a primary moult score of 41. Similarly an estimate of 149 days was obtained for a quelea (AD51983) trapped with a primary moult score of 24, and recaptured 66 days later with a primary moult score of 44, a discrepancy of 46 days.

This was repeated, using the mass of feather grown to remove the effects of feather size, which reduced this discrepancy to 31 days. The first individual replaced 50.2 mg of feather in 57 days while the second replaced 43.7 mg in 66 days. Rate of feather growth was therefore 0.88 and 0.66 mg/day respectively. For the above individuals to complete a moult of 84 mg of feathers would take 96 and 127 days respectively.

Timing of moult in individual quelea may be quite variable between years. One quelea ringed on 24 June 1998 with a primary moult score of 26 (41.8 mg of new feather growth), had a score of 41 (74.2 mg of new feather growth) when recaptured on the same day in 1999. Assuming that primary moult took an average 124 days in both years and that the mean moult rate was constant throughout at 0.68 mg/day (i.e. 84 mg in 124 days), this bird is estimated to have initiated primary wing moult on 23 April 1998 and on 7 March 1999.

5.3.2 Sequence of primary and secondary feather replacement in adult quelea.

The combined moult scores for each feather decreased from primary one to primary nine (Table 5.4). This demonstrates clearly that wing moult begins at the innermost primary (P1) and progresses sequentially to the tip (P9) with several primaries, usually at different stages of growth, often moulted simultaneously. Most of the birds in the sample had already completed moult of the first two primaries, hence the small difference in the scores for these two feathers.

Table 5.4 Primary wing feather moult sequence derived from the combined moult score for each primary of a random sample of 100 adult quelea from the Eastern Cape Province.

Feather number	1	2	3	4	5	6	7	8	9
Combined moult score	497	481	457	417	361	286	204	158	62
Moult sequence	1	2	3	4	5	6	7	8	9

Secondary moult was initiated at S8 at about the same time as P4 was shed and this was closely followed by S1 and S9 (Table 5.5). S2 and S7 were moulted at approximately the same time and were next in the sequence. Secondaries S1-S6 were moulted in ascending order and although S6 was the last wing feather to be dropped, moult of the shorter secondaries was completed soon after primary moult. Indeed, in a sample of 65 adult quelea with a primary moult score of 44 (i.e. primary moult almost completed), the average moult score for the nine secondary feathers was 40 (SD= 4). The right wing was usually examined, but where moult in both wings was recorded, it appeared symmetrical.

Table 5.5 Secondary wing feather moult sequence derived from the combined moult score for secondaries of a random sample of 100 adult quelea from the Eastern Cape Province.

Feather number	1	2	3	4	5	6	7	8	9
Combined moult score	349	246	168	127	90	51	216	394	312
Moult sequence	2	4	6	7	8	9	5	1	3

Note: The same birds were used to derive the scores for both the primaries and the secondaries

5.3.3 Incidence of multiple, simultaneous primary wing feather replacement.

In a random sample of 300 birds in various stages of moult 29%, 54%, 15% and 2% were replacing one, two, three and four primaries respectively (Table 5.6). Even birds in the early stages of moult (i.e. still growing P1) sometimes had up to three primaries at various stages of growth. Consequently, there were frequently considerable differences in the extent of growth of corresponding feathers between birds, despite similarities in their overall primary moult scores. P9 is the last primary to be shed, and in the later stages of moult is often the only remaining growing primary feather. Birds with the outermost primary growing were therefore excluded from this analysis as they might have artificially lowered the recorded incidence of simultaneous feather replacement.

Table 5.6 Number of quelea (from a random sample of 300 birds) moulting several primary feathers simultaneously, the percentage of birds in each category and the mean number of feathers moulted simultaneously (with standard deviation).

No. of growing primaries	1	2	3	4	Mean
n	87	162	45	6	1.9 (± 0.7)
	29	54	15	2	

The majority of birds in all months moulted one or two primary feathers at a time with a mean of 1.9 feathers (SD=0.7) (Table 5.6). All but two of the individuals moulting more than two primary feathers simultaneously were recorded in the first two months of the moult period (Table 5.7). This suggests that quelea are likely to moult primary feathers more rapidly in the early months of the moult period than later. Since primary moult progresses from P1-P9, it is to be expected that birds nearing completion of primary moult would only be growing one primary feather (i.e. P9).

Table 5.7 The mean moult scores (with standard deviation) of quelea moulting 1-4 primary feathers in each month of the moult period. Random samples of 30 birds were selected for each month except October, when only 16 birds were still growing primary feathers. Standard deviations are given in parenthesis.

Month	No. of growing primaries	n	Mean moult score
April	1	3	12 (± 10)
	2	13	19 (± 4)
	3	12	12 (± 6)
	4	2	12 (± 1)
May	1	13	28 (± 11)
	2	16	29 (± 10)
	3	1	28 (± 0)
	4	0	-
June	1	21	36 (± 10)
	2	9	17 (± 8)
	3	0	-
	4	0	-
July	1	9	42 (± 2)
	2	21	39 (± 2)
	3	0	-
	4	0	-
August	1	24	41 (± 4)
	2	6	40 (± 3)
	3	0	-
	4	0	-
September	1	17	37 (± 7)
	2	11	35 (± 5)
	3	2	36 (± 4)
	4	0	-
October	1	10	43 (± 3)
	2	6	39 (± 4)
	3	0	-
	4	0	-

5.3.4 Head, body and tail moult.

Timing of head, body and tail moult in relation to wing moult was quite variable. Some individuals (6%) were exclusively replacing wing feathers, while others had yet to initiate wing moult, but were already replacing head, body and/or tail feathers (9%) (Table 5.8). In most individuals, however, there was considerable overlap between these processes (85%) and it was not possible to tell where moult was initiated first.

Table 5.8 Timing of wing moult relative to other moult in 200 randomly selected quelea. Percentages of total birds sampled are given in parenthesis.

Moult	Number of quelea
Wing moult initiated - head, body & tail old	12 (6)
Wing moult and other moult	170 (85)
Head, body and/or tail moult initiated - wing old	18 (9)

5.3.5 Timing of wing moult in adult male and female quelea at Brandeston, Riverside Farm and Katkop/Lowlands Estate.

In a random sample of those individuals in primary moult which could still be sexed, there appeared to be considerable overlap between the timing of male and female moult, and no indication that one sex consistently started earlier than another (Table 5.9). Assuming a moult rate of 0.68 mg/day (Underhill-Zucchini model), on average males and females initiated moult within 20 days of one another. Males initiated moult before females at Riverside Farm in 1998, but in 1999 at Riverside Farm and in both years at Katkop/Lowlands Estate females initiated moult earlier on average. Differences between sexes were only significant for birds caught at Riverside Farm in 1999 (ANOVA, P=0.02).

Large standard deviations are to be expected given the relatively imprecise method of calculating the start of moult, but may also reflect the diverse origins of birds frequenting these farms. Quelea numbers fluctuated considerably through the year and it is likely that the populations on individual farms comprise a mixture of birds from different breeding colonies with different breeding dates and locations and hence different timing of post-nuptial moult. Birds in the 1998 sample for both sites were collected later in the year than those in 1999 and this may explain why the mean start of primary moult was later. Birds arriving later at the feedlots presumably bred later or further away. It is possible that quelea may migrate from considerable distances to areas that predictably offer an abundant source of food during the dry winter months.

Table 5.9 Timing of primary wing moult in male and female quelea at Riverside Farm and Katkop/Lowlands Estate in 1998 and 1999. Standard deviations are in parenthesis.

Farm	Year	Mean estimated start of primary moult		Mean estimated completion of primary moult	
		Male	Female	Male	Female
Riverside Farm	1998	23-05-98 (± 27) n=12	10-06-98 (± 37) n=10	24-09-98 (± 27) n=12	12-10-98 (± 37) n=10
	1999	25-03-99 (± 20) n=12	08-03-99 (± 13) n=12	27-07-99 (± 20) n=12	10-07-99 (± 13) n=12
Katkop/ Lowlands Estate	1998	23-04-98 (± 18) n=12	21-04-98 (± 11) n=11	25-08-98 (± 18) n=12	23-08-98 (± 11) n=11
	1999	27-03-99 (± 37) n=12	07-03-99 (± 22) n=12	29-07-99 (± 37) n=12	09-07-99 (± 22) n=12

5.3.6 Moult as a method of aging juvenile quelea.

Two of the juvenile quelea caught at Brandeston in April and May 1999 appear to have hatched at the same colony in early January, while the remainder hatched in February (Table 5.10). Assuming some variation in hatching dates within a colony (Jarvis & Vernon 1989b), and allowing for a margin of error in the moult key, it seems quite feasible that the birds estimated to have hatched in the first week of February were from the same colony (Table 5.10). Similarly, the birds hatched ten days apart, on the 13th and 23rd of February respectively, are likely to have come from the same colony. The origin of these birds is unknown, but no breeding colonies were observed or reported in the vicinity of Brandeston.

Table 5.10 Estimated age and hatching date of juvenile quelea caught at Brandeston in 1999.

Capture date	Primary moult score	n	Estimated age	Estimated hatching date	Estimated completion of moult
25-05-1999	26-30	2	143 days	02-01-1999	01-07-1999
27-04-1999	1-2	1	85 days	01-02-1999	31-07-1999
25-05-1999	16-20	1	110 days	04-02-1999	03-08-1999
25-05-1999	11-15	3	101 days	13-02-1999	12-08-1999
25-05-1999	6-10	8	91days	23-02-1999	22-08-1999

Juveniles caught in both February and June 1999 at Riverside Farm appear to have hatched from the same colony late in December 1998 (Table 5.11). The proximity of estimated hatching dates in mid-January, late January and early February, mid-

February, early March and late March suggest that these juveniles may have originated from as few as five additional breeding colonies. The location of these colonies relative to Riverside Farm is unknown, but the capture of very young quelea (≤ 55 days old) in February, March and April, at most two weeks after they gained independence from their parents, suggests that at least some may well have hatched nearby.

Table 5.11 Estimated age and hatching date of juvenile quelea caught at Riverside Farm in 1999.

Capture date	Primary moult score	n	Estimated age	Estimated hatching date	Estimated completion of moult
17-02-1999	0	13	≤ 55 days	on or after 24-12-1998	on or after 22-06-1999
22-06-1999	41-45	1	180 days	24-12-1998	22-06-1999
11-03-1999	0	8	≤ 55 days	on or after 15-01-1999	on or after 14-06-1999
22-06-1999	31-35	1	154 days	19-01-1999	18-06-1999
12-05-1999	16-20	1	110 days	22-01-1999	21-06-1999
10-05-1999	11-15	1	101 days	29-01-1999	28-06-1999
22-06-1999	26-30	2	143 days	30-01-1999	29-06-1999
10-05-1999	6-10	3	91 days	08-02-1999	07-08-1999
12-05-1999	6-10	2	91 days	10-02-1999	09-08-1999
13-04-1999	0	22	≤ 55 days	on or after 16-02-1999	on or after 15-08-1999
22-06-1999	21-25	3	125 days	17-02-1999	16-08-1999
22-06-1999	16-20	3	110 days	04-03-1999	31-08-1999
10-05-1999	6-10	1	91 days	08-03-1999	04-09-1999
22-06-1999	6-10	2	91 days	23-03-1999	19-09-1999

It is possible that quelea bred in the vicinity of Katkop/Lowlands Estate since juveniles less that two months old were captured there in March 1999. Earliest breeding in the 1998-1999 season appears to have been in late December (Table 5.12), with additional colonies hatching chicks in mid-January, early and late February, and late March. Since suitable conditions for quelea to breed (i.e. abundant insects and fresh grass seeds) are only available for a limited period in each area after the rain, chicks that hatched several months apart are likely to have come from widely separated breeding colonies.

Table 5.12 Estimated age and hatching date of juvenile quelea caught at Katkop/Lowlands Estate in 1998 and 1999.

Capture date	Primary moult score	n	Estimated age	Estimated hatching date	Estimated completion of moult
03-06-1998	21-25	4	125 days	29-01-1998	28-07-1998
30-05-1999	31-35	1	154 days	27-12-1998	25-06-1999
10-03-1999	0	13	≤ 55 days	on or after 14-01-1999	on or after 13-07-1999
30-05-1999	16-20	1	110	09-02-1999	08-08-1999
16-06-1999	16-20	2	110	26-02-1999	25-08-1999
21-08-1999	31-35	1	154	20-03-1999	16-09-1999
21-08-1999	26-30	1	143	31-03-1999	27-09-1999

Birds that hatched at the end of March would only be expected to complete primary wing moult by sometime in September and may account for at least a proportion of the late moult recorded. At Riverside Farm and Katkop/Lowlands Estate, juveniles presumed to have originated from early breeding attempts completed primary wing moult before adults, while those from later breeding attempts completed wing moult up to two months after the adults in some years.

5.3.7 Interrupted moult.

Only three quelea showed very unusual moult patterns that could not be explained by the loss or damage of feathers. Two birds were males and one was a female, and all three were captured at Katkop and had two moult cycles proceeding in the same wing. The two males were captured in late April 1998 and the female in early June 1998. One male had replaced primaries up to P4 before moult was interrupted while the other two birds had also replaced P5. All three birds had subsequently re-initiated moult from the point of interruption but had also begun a new cycle from P1. The males were also undergoing extensive head and body moult, but still showed traces of breeding plumage. The female only had tail moult.

5.3.8 Pre-nuptial moult and changes in bill colour.

The proportion of adult quelea of unknown sex in the Eastern Cape population increased dramatically after April as post-nuptial moult progressed, and by July birds could only be sexed after an examination of their reproductive organs (Table 5.13). Although a few of the most precocious birds began pre-nuptial moult in August (Table

5.14), the majority of the quelea population at the feedlots first showed signs of moult or bill mottling in September or October. Details of pre-nuptial moult and change in bill colour were only collected for a small subset of all birds handled.

A large proportion of the quelea collected between May and September were not sexed because there were no suitable external diagnostic features to facilitate this (Table 5.13) and only a small sample was kept for dissection. Consequently, the proportion of females in the population with red bills is likely to have been underestimated over most of this period, except in July and August when all females were in non-breeding condition and displayed uniformly red bills (Table 5.15).

Table 5.13 Proportion of adult quelea sampled in each month that were not or could not be sexed.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
%	1	1	0	30	74	86	99	92	76	23	5	<1
n	301	154	22	102	534	1426	1247	519	87	414	206	276

A few of the most precocious males began pre-nuptial moult in August and by October all males had initiated moult (Table 5.14). Progress of pre-nuptial moult was not scored, but judging from an individual (AF37606) ringed at the end of September 1998 while in the early stages of moult, and recaptured in full breeding plumage approximately one month later, duration of pre-nuptial moult was estimated at just over one month. This is consistent with the observation that the first birds in full breeding plumage were found one to two months after the first nuptial moult was recorded. A study of individually marked caged birds will be required if the duration and the pattern of progression of pre-nuptial moult is to be plotted accurately.

Table 5.14 Number of known adult male quelea captured in different months at Katkop/Lowlands Estate and Riverside Farm for which moult was recorded and the percentage of these in non-breeding plumage, transitional plumage and nuptial plumage.

Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Non-breeding plumage	100	94	70	0	0	0	0
Transitional plumage	0	6	30	98	57	25	0
Nuptial plumage	0	0	0	2	43	75	100
N	16	32	95	261	150	179	207

A male quelea ringed in breeding plumage in 1997 and re-trapped during the 1998-1999 breeding season, had the same nuptial plumage on both occasions. This suggests that the morph type (i.e. appearance of an individuals breeding plumage) is genetically, rather than environmentally controlled. Environmental factors may well influence the timing of moult.

Female quelea initiated pre-nuptial moult after males and the first female with a mottled bill was observed in September (Table 5.15). By November, all females had either mottled or bright yellow bills and by January all males and all but a few females were in full breeding plumage. Although pre-nuptial moult took approximately six months for the whole population to complete, individual birds may enter breeding condition relatively rapidly (i.e. less than two months) and the process may be tightly synchronised. Indeed, the majority of individuals of both sexes (75%) completed moult over a four-month period (September to December).

Table 5.15 Numbers of known adult female quelea captured in different months at Katkop/Lowlands Estate and Riverside Farm for which bill colour was recorded and the percentage of these with red, transitional and yellow coloured bills.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red bill	0	0	0	14	56	45	100	100	39	13	0	0
Transition	5	36	37	43	33	55	0	0	61	55	53	24
Yellow bill	95	64	63	43	11	0	0	0	0	32	47	76
n	91	105	8	21	18	20	1	12	23	56	45	95

5.3.9 Mask Types.

A wide variety of male morphs were identified over the course of the study. These corresponded roughly to the four main types described by Lourens (1963). Morphs either had a dark face mask (Plate 9) (in this region masks were brown rather than black, but ranged from dark almost black brown, to light brown) or a white face mask (Plate 10) that was often difficult to distinguish from the colouration of the rest of the head. Birds belonging to the pale morph are termed russi, derived from the fact that male quelea with white faces were previously considered to be a distinct species, *Quelea russi* (Ward 1966).

Plate 9 Male quelea in breeding plumage (dark-faced morph).

Plate 10 Male quelea in breeding plumage (white-faced morph).

Masked and russi morphs could be further divided into those with a dark mask and buff crown and throat (Buff-mask), or dark mask with the buff areas suffused with pink (Red-mask), or a white/buff-coloured mask with either a buff crown and throat (Buff-russi) or white mask/buff-coloured mask and pink suffusion (Red-russi). There was also some variation in the width of the frontal band (Figure 5.1), but Lourens (1963) did not score this. A further category contained aberrations of these forms including buff morphs (both masked and russi types) with pink on the chest and/or belly, but not on the crown and sides of neck, and russi types with incomplete masks.

Table 5.16 Proportions of each male morph in various quelea populations in southern Africa. The South African sample was collected from colonies throughout South Africa (excluding the Eastern Cape) in the 1950s and 1960s (Lourens 1963). Eastern Cape samples were collected between 1997 and 1999.

Location	n	Red-mask	Red-russi	Buff-mask	Buff-russi	Aberrations
South Africa (Lourens 1963)	5022	43.3	6.0	41.3	5.8	3.6
Zimbabwe (Lourens 1963)	364	43.1	5.8	39.3	7.4	4.4
Botswana (Lourens 1963)	331	44.1	6.7	40.2	4.8	4.2
"spoliator" (Clancey 1973)	23	43.4	13.1	39.1	4.3	0
Cradock 1997-1998	145	45.5	13.8	31.7	4.8	4.1
Cradock 1998-1999	293	52.6	9.9	23.9	4.4	9.2
Cookhouse 1997-1998	163	54.6	8.6	27	4.3	5.5
Cookhouse 1998-1999	386	51.6	9.1	25.7	4.1	9.6

Lourens' (1963) sample for South Africa included colonies from within both the breeding range of *lathamii* and the proposed breeding range of *"spoliator"* (Table 5.16) and were therefore excluded from all further analysis. His samples from Botswana and Zimbabwe were, however, from the breeding range of *lathamii* alone and provided a useful comparison for the small *"spoliator"* sample collected by Clancey (1973) and the, as yet, uncategorized birds from the Eastern Cape.

A chi-squared test of homogeneity showed significant differences (χ^2=68.2; df=23; P<0.005) in the proportion of the different male morphs amongst the populations shown in Table 5.16. There were, however, no significant differences amongst the quelea collected by Lourens (1963) from the range of *lathamii* in Zimbabwe and Botswana (χ^2=2.5; df=3; P>0.25) nor amongst the four samples collected from the Eastern Cape between 1997 and 1999 (χ^2=13.3; df=11; P >0.25). There were significant differences between Eastern Cape quelea and those collected by Lourens (1963) in Botswana and Zimbabwe (χ^2=64.5; df=19; P <0.005), but surprisingly, Clancey's (1973) "*spoliator*" sample was similar (χ^2=3.8; df=7; P >0.75) to both the *lathamii* samples from Botswana and Zimbabwe and the Eastern Cape samples (χ^2=16.3; df=15; P >0.25). The Clancey sample therefore appears to be intermediate between the true *lathamii* and Eastern Cape samples. Due to the different ages of the samples and the small size of the "*spoliator*" sample, it is not possible to draw any firm conclusions from these findings. Furthermore, Clancey did not claim that "*spoliator*" and *lathamii* could be distinguished on the basis of breeding plumage.

To determine whether it was the proportion of mask versus russi types that differed or whether it was the proportion of individuals with pink plumage, further analysis was required. The proportions of russi to masked type individuals and proportions with and without pink suffusions were compared for samples from the known range of *lathamii* and those from the Eastern Cape (Table 5.17). Birds with aberrant plumage were excluded from the analysis.

All populations showed similar proportions of mask and russi type individuals (Table 5.17) (χ^2=8.4; df=5; P >0.1). However, while there were no significant differences in the proportion of quelea with pink suffused plumage among Eastern Cape sites (χ^2=2.0; df=2; P >0.25), significantly more quelea collected in this region had pink suffused plumage than in populations sampled by Lourens (1963) in Zimbabwe (χ^2=27.8; df=3; P <0.005) and Botswana (χ^2=20.7; df=3; P <0.005). This then appears to be the main characteristic distinguishing Eastern Cape quelea from those within the accepted range of *lathamii*.

The width of the frontal band, though not recorded by Lourens (1963), was more variable between years at Cookhouse than other plumage characteristics. This may be attributed to the absence of a precise measurement for this character and the fact that the band may not have been complete (despite the absence of growing feathers) in all birds sampled during the earlier part of the pre-nuptial moult. Nevertheless, there were no significant differences among the four Eastern Cape samples (χ^2=19.5; df=14; P >0.1), but the frequency of the various frontal band widths were significantly different from birds collected in Botswana by R. Allan (1994, unpublished data) (χ^2=280; df=4;

P <0.005) (Table 5.17). Similarly, there was considerable variability among samples collected at different sites in Botswana (R. Allan 1994, unpublished data, pers. comm.). Apart from the data for Basinghall Ranch (Table 5.17), samples were collected from ten other sites in Botswana. Proportions of russi types varied from 13-19% while percentage with frontal bands of 6&7 ranged from 58.7-97%. Most of these samples were of well below 100 birds, but it does suggest substantial variability among populations within a single country. There were no significant differences in the proportion of birds with pink eyebrows among samples collected at Cradock, Cookhouse and Villiers (χ^2=2.0; df=1; P >0.1) (Table 5.18).

Mean morphological measurements (wing length and bill length, width and depth) of adult birds appeared very similar among sites (Table 5.18), but these differences were nevertheless significant for all characteristics (MANOVA, P <0.001). Differences in bill measurements were only moderately consistent among sites (i.e. birds from the three sites did not rank in the same order according to mean bill length, width and depth). These inconsistencies may be attributed to differences in bill shape among sites, since differences in size alone would be more consistent.

Male quelea from the Eastern Cape were significantly larger than females with regard to all bill and wing measurements (MANOVA, P <0.001), but there was considerable overlap (Table 5.19). Since females at the two Eastern Cape sites were similar and males at the two Eastern Cape sites were similar (MANOVA, P<0.41), it is possible that apparent differences in the mean bill sizes of birds from these populations can be attributed to differences in the sex ratios of the samples from each site. The Free State sample was not sexed, but ratios of male to female quelea were slightly higher at Riverside Farm (2.7:1) than at Katkop/Lowlands Estate (2.6:1), which would contribute, at least partially, to the larger average bill size of the Riverside Farm birds.

The Eastern Cape measurements were means of all adult birds (sexes combined) in all months, whereas those for the Free State were mainly for birds that had recently completed post-nuptial moult. Differences in wing length between Free State and Eastern Cape birds are therefore likely to have been influenced by feather growth and wear.

Table 5.17 Proportion of russi and mask type males in the quelea populations sampled by Lourens (1963) Zimbabwe and Botswana, by Allan in Botswana in 1994, and in the Eastern Cape between 1997 and 1999. Aberrations of the various morphs were excluded from the analysis for all samples.

Site	n	% russi type	% mask type	% with pink suffusion	% without pink suffusion	Extent of frontal band (percentage of birds with each type)					
						1	2	3	4	5	6 & 7
Zimbabwe (Lourens 1963)	348	13.8	86.2	51.2	48.8						
Botswana (Lourens 1963)	317	12.0	88.0	53.0	47.0						
Botswana 1994 (Allan 1994, unpublished data)	253	19.0	81.0				0.5	1.0	7.0	32.5	59
Cradock 1997-1998	139	19.4	80.6	61.9	38.1				1.0		99
Cradock 1998-1999	266	15.8	84.2	68.8	31.2				0.4	2.0	97.6
Cookhouse 1997-1998	154	13.6	86.4	66.9	33.1						100
Cookhouse 1998-1999	349	14.6	85.4	67.0	33.0				0.9	5.2	93.9

Table 5.18 Other morphometric data and plumage characteristics of quelea from the Eastern Cape and Free State (± standard deviation). Mass data are live weights of birds in breeding plumage, while bill and wing measurements are for live and dead adult birds collected in all months. All samples for eyebrow analysis were collected during winter 1999. Data for male and female quelea are combined. (PE - pink streak in eyebrow stripe; NPE - no pink streak in eyebrow stripe).

Location	n	% PE	% NPE	n	Bill length (range)	Bill Width (range)	Bill depth (range)	n	wing length (range)	n	Mass (range)
Villiers, Free State (September 1999)	647	71.2	28.8	100	14.3 ± 0.4 (13.3-15.3)	7.1 ± 0.2 (6.6-7.8)	9.7 ± 0.3 (9.0-10.4)	100	66.3±1.6 (62-69)		
Cradock, Eastern Cape (1997-1999)	1186	68.2	31.8	304	14.5 ± 0.4 (13.3-15.5)	7.1 ± 0.2 (6.6 - 7.5)	9.6 ± 0.3 (8.7-11.0)	812	65.4± 1.9 (60-76)	559	19.2 ± 1.6 (14.2-29)
Cookhouse, Eastern Cape (1997-1999)	507	70.0	30.0	330	14.6 ± 0.5 (13.0-16.0)	7.1 ± 0.2 (6.6-8.3)	9.8 ± 0.4 (8.7-10.8)	1124	65.5±1.8 (59-71)	820	19.5 ± 1.6 (13-26.5)

Table 5.19 Comparison of morphometric data for adult male and female quelea at Riverside Farm and Katkop/Lowlands Estate. Mass data are live weights of birds in breeding plumage, while bill and wing measurements are for live and dead birds collected in all months (± standard deviation).

Locality and sex	n	Wing length (range)	n	Bill length (range)	Bill width (range)	Bill depth (range)	n	Mass (range)
Riverside Farm male	866	66.0 ± 1.6 (60-71)	243	14.7 ± 0.4 (13.6-15.7)	7.2 ± 0.2 (6.0-8.3)	9.8 ± 0.4 (8.9-10.8)	627	19.7 ± 1.6 (15.0-26.5)
Riverside Farm female	258	63.9 ± 1.5 (59-68)	89	14.3 ± 0.5 (13.0-16.0)	7.0 ± 0.2 (6.6-7.9)	9.6 ± 0.3 (8.7-10.4)	193	18.9 ± 1.6 (13-24)
Katkop male	612	65.9 ± 1.7 (61-76)	220	14.6 ± 0.4 (13.7-15.5)	7.1 ± 0.2 (6.7-7.5)	9.6 ± 0.3 (8.7-11.0)	427	19.5 ± 1.5 (15.5-29)
Katkop female	200	64.0 ± 1.5 (60-68.5)	84	14.1 ± 0.3 (13.3-15.0)	7.0 ± 0.2 (6.6-7.5)	9.5 ± 0.4 (8.7-10.9)	132	18.4 ± 1.6 (14.2-28.5)

5.4 DISCUSSION

Moult is an energetically demanding process (King 1980; Underhill 2000) and as such one would expect it to be kept separate from other physiologically stressful periods in the annual cycle. These include the breeding season and the lean, cold winter months (June-August) when diminishing food supplies coincide with increased thermoregulatory costs (Tinney 1997) and mortality of quelea may be high (Ward 1964; Vernon 1989).

Although there is evidence of limited moult/breeding overlap in this species, post-nuptial moult is usually suspended to separate these energetically expensive processes when additional breeding attempts are made (Thompson 1988). Two simultaneous cycles of moult were recorded for only three individuals in this study. This "staffelmauser" or stepwise moult is a feature of non-passerines, but has been previously recorded for quelea (Elliott & Lenton 1989) and suggests that these birds suspended post-nuptial moult to allow a second breeding attempt. Interruption of moult is considered rare in southern African quelea populations, but is more common in eastern Africa (Jones 1989c).

Since post-nuptial moult is initiated towards the end of breeding (Elliott & Lenton 1989), its timing is to a large extent dependent on the timing and duration of the breeding season. Consequently, regional as well as between year differences in the same area are to be expected, depending on when conditions are most suitable for breeding.

Thompson (1988) found that male quelea at colonies in Kenya initiated post-nuptial moult before females. He suggested that during reproduction female quelea might experience greater physiological demands than males, especially when more than one clutch is produced in a season, hence the delay in moult. In contrast, there was considerable overlap in the timing of male and female post-nuptial moult in the Eastern Cape and no consistent trend as to which sex initiated moult first. Differences between sexes in the estimated mean start of moult never exceeded 20 days. Following Thompson's arguments (Thompson 1988), since female quelea in the Eastern Cape do not appear to delay the onset of post-nuptial moult, they do not appear to be at any energetic disadvantage to males. This, together with the low recorded incidence of interrupted moult in this region, suggests that quelea spending the dry season in the Eastern Cape rarely raise more than one brood in a season.

While other ploceids in the Eastern Cape may begin breeding as early as September (Craig *et al.* 2001) with the first flush of insects, nestling quelea are fed only fresh grass seeds after the first week and thus breeding must wait until the rains are well advanced in order to coincide with the new crop of grass seeds (Lourens 1963; Jones 1989c; Jones 1989d). In this study, quelea breeding appeared to be concentrated between January and March and post-nuptial moult began only in April. This is in close agreement with the observations from other areas of South Africa (Lourens 1963) and Zimbabwe (Tree 1965), but is a month or more later than other ploceid species in the Eastern Cape (Craig *et al.* 2001). When conditions are suitable, quelea would be expected extend their breeding season in order to maximise their reproductive output and breeding may continue until May in some years (Mundy & Herremans 1997). This would delay the onset of post-nuptial moult still further.

Timing of the start of moult was more variable in quelea (Standard deviation of 36.5 days) than in Masked and Cape Weavers (Craig *et al.* 2001), but less variable than in Spotted-backed Weavers and Red Bishops measured in the same study. Since European Starlings in England collected from a single population of resident birds at one locality showed well synchronised moult (Rothery *et al.* 2001), much of the variability encountered with the other species may be attributable to spatial and temporal differences in rainfall patterns and the hence timing of breeding among birds sampled at different localities and in different years. This may be especially so for quelea given that they may disperse over considerable distances to breed before returning to reliable overwintering areas (Chapter 4). However, captive quelea from a single flock also showed considerable variation in the timing of the start of moult (Lourens 1963) and similar variability has been reported for Red Bishops (Craig & Manson 1979). Consequently, other factors such as individual fitness (possibly related to the number of breeding attempts) and location of breeding grounds relative to overwintering areas, are also likely to influence the timing and duration of moult.

Mean duration of primary wing moult estimated for quelea in this study using the Underhill-Zucchini model was 124 days, similar to previously published estimates of approximately three (Lourens 1963; Ward 1973b) to four months (Thompson 1988) for this species. Moult rate may, however, vary within individuals at different stages of moult, mainly due differences in the number of growing feathers (Newton 1966). Rothery *et al.* (2001) argue that such variation produces a non-linear increase in the moult score over time and since the Underhill-Zucchini model assumes a linear increase, it may underestimate the true duration of post-nuptial moult. Quelea in this study were found to be replacing from one to four primary feathers simultaneously and a study of moult in captive birds is required to improve the accuracy of estimates of the timing and duration of moult (Rothery *et al.* 2001).

In the absence of repeated recaptures of the same marked individuals at different stages of moult, a constant rate of feather replacement was an underlying assumption of the mark-recapture method used to estimate moult duration in this study. Given that moult rate may vary within an individual at different stages of moult (Newton 1966), the large discrepancy (33 days) between the estimated duration of moult in the two mark-recaptured quelea may largely be an artifact of the estimation technique. However, the individuals in question were moulting two and three feathers respectively and actual differences in the overall rate of feather replacement between individuals should not be ruled out. Although recent work on European Starlings suggests that temporary decreases in food availability do not affect overall duration of primary moult (Swaddle & Witter 1997), the nutritional status of the individuals is thought to influence the timing and duration of pre-nuptial moult (Lourens 1963; Jones 1989c) and may well influence post-nuptial moult in a similar manner.

While the duration of primary feather replacement in quelea estimated using the Underhill-Zucchini model was similar to that of Cape Weavers *Ploceus capensis* (106 days) and Spotted-backed Weavers (109 days) (Craig *et al.* 2001) it was considerably longer than for both Masked Weavers (67 days) and Red Bishops (89 days) and is considered relatively slow in comparison to other tropical species (Craig & Manson 1979). It is inevitable therefore, when considering the later breeding season of quelea, that while the majority of adult individuals of these other species successfully completed moult by autumn or early winter (June) at the latest (Craig *et al.* 2001), a large proportion of the quelea population continued to moult throughout winter. Indeed, some individuals were still replacing flight feathers when more precocious individuals were already entering breeding plumage.

In the Eastern Cape, the main post-nuptial moult period lasted approximately six months in the quelea population as a whole. This is similar to estimates of moult duration reported for quelea in other areas of South Africa (Lourens 1963) and west Africa (Morel & Bourlière 1955, in Craig 1983), but is longer than the four months estimated by Tree (1965) for adult and juvenile quelea in Zimbabwe.

As winter progresses, quelea are faced with growing food shortages and increased thermoregulatory costs. A slow moult might therefore be explained by the need to spread the costs of feather replacement over a longer period. This cannot, however, be the whole explanation as Cape Weavers also undergo a comparatively slow moult, and this at a time when food is still abundant and other species such as Masked Weavers and Red Bishops are moulting rapidly (Craig *et al.* 2001). In the absence of an abundant food source during winter (e.g. feedlot), quelea are typically highly nomadic. However, moult creates gaps in flight feathers that increase drag and thereby reduce flight efficiency (Hedenström 1998; Underhill 2000) and a slow replacement of wing feathers would be expected to minimise disruption of flight capabilities. Such a strategy would be crucial to the foraging success of quelea and ultimately to their survival.

Simultaneous replacement of several primary feathers would appear to negate any benefits of a slow moult in individuals that need to retain their full flight capabilities. However, all but two quelea moulting more than two primary feathers simultaneously were recorded during the first two months of post-nuptial moult in the population (April and May) at a time when food might still be expected to be relatively abundant, temperatures still moderate and the need for energy saving and extensive movements in search of food would be minimal. In the later stages of moult, the additional costs of moulting secondary feathers after P4 is shed, or the increased thermoregulatory costs, or the need for increased nomadic movements in search of diminishing food supplies, or a combination of these factors might be expected to constrain multiple simultaneous primary feather replacement.

The technique used to assess moult sequence is simplistic in that differences in the size of individual wing feathers and variations in moult rate due to energetic demands of multiple simultaneous feather replacement are not accounted for. Nevertheless, the sequence of primary and secondary wing feather replacement in quelea was fairly consistent and was similar to that recorded for the House Sparrow (Ginn & Melville 1983), Red-headed Finch *Amadina erythrocephala* (Raijmakers 1992) and indeed the normal moult pattern of South African birds in general (de Beer *et al.* 2000). There was, however, no consistency with regard to the timing of head, body and tail moult in relation to wing moult and these processes overlapped considerably in the majority of individuals. While overlap of wing, head and body moult appears to be normal, primary moult is usually initiated before head and body moult (de Beer *et al.* 2000).

The start of pre-nuptial moult in the quelea population coincided with first rains in the Eastern Cape in September (Chapter 2) and by October, when the main rainfall period began, the most precocious males and females were already in full breeding plumage. Thus while pre-nuptial moult may be completed relatively rapidly by individual birds, there was considerable asynchrony in the population and moult extended until January. Asynchrony in pre-nuptial moult appears to be typical of quelea (Jones 1989d) and may be related to the nutritional status of individual birds.

By the time all the overwintering quelea had completed moult, local conditions were again suitable for breeding. Of the juveniles subsequently captured at the feedlots, the oldest were estimated to have hatched in January, the start of the main quelea breeding season in southern Africa (Lourens 1963), and the youngest in March. Although no successful breeding was observed in the immediate vicinity of the feedlots, these birds may nevertheless have originated from undetected breeding colonies located nearby.

On average, male quelea in the Eastern Cape appeared slightly larger than females with regard to wing length, mass, and bill measurements, although there was considerable overlap. Male quelea are solely responsible for nest construction (Jarvis & Vernon 1989b) and while it may be speculated that their larger bill affords benefits for the collection of materials or in the weaving process there is, as yet, no indication that males with smaller bills are at a disadvantage. Ward (1965) suggested that the relatively stouter bills of male quelea would allow them to take larger seeds than females during periods of food shortage. This seems like a more plausible explanation, as any potential reduction in intra-specific competition for food would be to the benefit of all individuals even if there were considerable overlap in bill size between sexes.

On average, the Riverside Farm birds tended to be larger than those from Katkop/Lowlands Estate and Villiers, but these differences may be at least partially attributable to differences in the sex ratio of samples from each site. Because the bill is abraded during feeding, measurements of this feature may vary depending on the foraging habits of birds (Ward 1965), the local habitat in which samples were collected, the season in which samples were collected and possibly even the age of birds sampled. As a result, bill measurements are considered unsuitable morphometric characteristics for distinguishing reproductively isolated populations.

Characteristics such as live weight and wing length are also considered unsuitable for separating different bird populations since individual birds show great variability over time, depending on how much food is stored in the crop (Elliott 1998) and the age of the wing feathers (Linz *et al.* 1993a) respectively. Characteristics that are genetically determined such as differences in plumage colouration are more reliable. These have been used by other authors (Clancey 1960; Lourens 1963; Ward 1966; Clancey 1973; Jones *et al.* in press) and appeared the most useful in this study.

The similarity in the ratios of quelea with and without pink in the eyebrow stripe in samples collected hundreds of kilometres apart from two sites in the Eastern Cape and a single site in the northern Free State supports the concept of a continuous *lathamii* population in South Africa. At the very least, such observations suggest substantial mixing of populations during the non-breeding season. There is now also evidence from ringing recoveries (Chapter 4) that interchange of birds between these areas does indeed occur, although the scale of these movements is not yet known. While a genetic basis for the development of a pink streak in the white eyebrow stripe of quelea in non-breeding plumage still remains to be demonstrated, mask characteristics are thought to be genetically controlled (Lourens 1963) and there is no reason to suspect otherwise for non-breeding colouration. In southern Africa, quelea with pink eyebrow streaks have been observed in samples from the Eastern Cape, KwaZulu-Natal, the Free State, the Northwest Province and Zimbabwe. Suitably large samples of non-breeding birds from throughout this region are now needed to determine the true potential of this characteristic as a means of distinguishing non-breeding populations. If a method of scoring the extent and intensity of the streak could be developed, additional useful data may be forthcoming.

It is generally accepted that for speciation to take place birds must be geographically isolated, at least with regard to breeding areas, and it is through this isolation that differentiating characteristics may develop. Thus, while the ranges of the races *aethiopica* and *lathamii* are reported to overlap in northern Zambia during the non-breeding season, they are assumed to depart in different directions to breed, and there is no evidence of hybridization between these races (Irwin 1989). It is therefore tempting to speculate that the increased sedentariness and localised breeding suggested for quelea in the Eastern Cape (Chapter 4) may separate them, at least in terms of breeding, from the more nomadic flocks from the north despite the apparent mixing of these populations during the non-breeding season.

Significant differences in the breeding plumage of male quelea have been found between recent samples from the Eastern Cape and populations sampled in the 1950s and 1960s in Zimbabwe and Botswana (Lourens 1963). These differences were not related to the relative percentages of russi and mask type individuals, but rather to the number of individuals with pink colouration on the head and/or chest. Comparing samples from different areas, and collected over large time intervals, is however of questionable value, especially since a high proportion of "pink" individuals is one of the characteristic features of *lathamii* (Ward 1966). Differences between Lourens' samples and those collected more than 30 years later in the Eastern Cape may therefore simply reflect a general shift in the *lathamii* population as a whole, towards a greater proportion of "pink" individuals. Thus while the proportion of "pink" individuals is a potentially useful characteristic for distinguishing Eastern Cape birds, the existing population profile for *lathamii* (Lourens 1963) is possibly outdated and more recent samples collected from throughout South Africa are required for comparison. Width of the frontal band appears to be a useful distinguishing characteristic, but too little data are currently available for southern African quelea to draw any reliable conclusions.

Unlike *aethiopica* and *lathamii*, *"spoliator"* and *lathamii* types show extensive overlap of their non-breeding ranges, and proposed differences in non-breeding plumage (Clancey 1960; Clancey 1973) are completely unsupported by any corresponding differences in the mask index of males (Jones *et al.* in press). In the absence of any consistent differences in breeding plumage between *lathamii* and *"spoliator"* and any behavioural barriers to prevent interbreeding (including timing of breeding attempts), Jones *et al.* (in press) consider it unlikely that any genetic differences between these two supposed subspecies could be maintained. Quelea show wide colour variation and both lighter *lathamii* and darker *"spoliator"* type individuals may be found in the same colony (Jones *et al.* in press). Furthermore, light coloured parent birds may produce both lighter and darker offspring (Lourens 1963).

Re-examination of museum specimens classified as either *lathamii* or *"spoliator"* by P.A. Clancey and examination of additional specimens from southern Africa, revealed that *lathamii* and *"spoliator"* type individuals comprised only a small proportion of the sample and corresponded to the two extremes of a continuous variation in colour (Jones *et al.* in press). Lourens (1961, 1963), Ward (1966) and most recently, Jones *et al.* (in press) have all therefore, rejected *"spoliator"*. Ward (1966) also rejected two other races *Quelea quelea centralis* (Van Someren) of the eastern part of the Democratic Republic of Congo (formerly Zaire) and *Quelea quelea intermedia* (Van Someren) of Tanzania and surrounding areas on the basis that they referred to very variable populations, possibly of hybrid origin, and thus subspecies status was unjustified.

5.5 CONCLUSIONS

The main breeding season for quelea overwintering in the Eastern Cape may extend into March in some years. When combined with an average post-nuptial moult in excess of four months, many quelea are unable to complete moult before the onset of the dry winter period. As food supplies dwindle and ambient temperatures drop, it is vital that quelea retain a high degree of both their flight and insulatory capabilities and a slow moult would allow them to achieve both these objectives. Feather replacement followed the expected sequence and the incidence of interrupted moult was low, suggesting that quelea overwintering in this region rarely raise more than one brood.

Quelea populations from the undisputed breeding range of *lathamii* in Zimbabwe and Botswana have similar proportions of russi and mask type individuals to populations in the Eastern Cape. Populations at Cookhouse and Cradock did have a higher proportion of pink-suffused males, but the relative ages of the samples makes drawing of direct comparisons difficult. Similarities in non-breeding plumage between Eastern Cape birds and those from a site in the Free State, together with direct evidence of movements between these areas provide further support for a single, integrated *lathamii* population in southern Africa. This is in agreement with the most recent findings of other researchers (Jones *et al.* in press).

6 CHAPTER SIX

DIET AND ESTIMATED DAMAGE BY GRANIVOROUS BIRDS AT OSTRICH FEEDLOTS

6.1 INTRODUCTION

Quelea have long been recognised as an economically important species but until relatively recently accurate damage assessments were lacking (Ward 1979). Subsequently, increased efforts have been made in this regard (Elliott 1989b) and a standardised survey method has recently been proposed for assessing damage to field crops (Allan 1996).

Several authors refer briefly to quelea feeding on crushed maize obtained either from fields after mechanical harvesting (Erickson 1989; Jarvis & Vernon 1989a) or from livestock feed troughs (Jarvis & Vernon 1989a). While Jarvis & Vernon (1989a) observed that supplementary livestock feed was exploited by quelea towards the end of the dry season in certain areas, Berruti (1995) was the first to demonstrate the importance of this artificial food source in the diet of quelea throughout the year. Birds are responsible for substantial feed losses at intensive animal rearing and grain storage facilities around the world (Besser *et al.* 1968; Feare 1975; Feare & Swannack 1978; Feare & Wadsworth 1981; Glahn *et al.* 1983 and references therein; Feare 1984 and references therein; Toor *et al.* 1986) and accurate assessments of the problem are essential to the successful implementation of cost-effective management strategies (Weatherhead *et al.* 1982). A wide variety of bird species including Helmeted Guineafowl *Numida meleagris*, pigeons, doves, Wattled and Pied Starlings, quelea, bishops, weavers, sparrows, canaries and firefinches exploit the artificially abundant food sources available at livestock feedlots in the Eastern Cape Province. However, until now, no attempt has been made to assess the economic value of bird damage at intensive livestock feeding operations in South Africa.

While direct assessment of damage is possible for field crops (Dawson 1970; Otis 1989; Berruti 1995; Allan 1996), an indirect approach is required to distinguish feed consumption by livestock from that of problem birds. A number of models have been developed to indirectly assess feed losses due to birds (Besser *et al.* 1968; Feare 1975; Feare & Swannack 1978; Folk & Kožená 1982; Glahn *et al.* 1983; Toor *et al.* 1986). The models usually require several basic inputs including estimates of the number of birds utilising the food source over the study period, the daily food consumption of the various problem species, the proportion of stock or stored feed in the birds diet, and the value per kilogram of the food eaten. The main difference between models appears to be in the method for estimating the proportion of feed in the birds diet and their daily consumption.

Different authors have variously derived daily consumption values for problem birds from energetic equations (e.g. Toor *et al.* 1986), from direct measurements with caged birds (e.g. Besser *et al.* 1968) or from published data (e.g. Folk & Kožená 1982). Dietary information was obtained either from observations of feeding behaviour (e.g. Besser *et al.* 1968) or by examining gut contents (e.g. Folk & Kožená 1982; Toor *et al.* 1986). Feare (1975) and Feare & Swannack (1978) obtained equivalent information from measurements of the time birds spent feeding on cattle feed and feeding rates, while Glahn *et al.* (1983) related the number and duration of visits to a trough to the amount of food eaten. These latter two methods provide no information on the other components of the diet of problem birds and were thus inappropriate for this study.

The aims of the work reported in this chapter were to assess seasonal variations in the importance of crushed maize from livestock feedlots in the diet of various granivorous birds, with particular reference to quelea and Laughing Doves. It was hypothesised that these species would be most dependent on artificial food sources from autumn to early spring, before the new grass had set seed. To test this, the amount and value of feed removed from ostrich feedlots at Riverside Farm and Katkop was estimated through the year.

6.2 MATERIALS & METHODS

6.2.1 Estimate of maize removed by quelea, Laughing Doves and other granivorous species from ostrich feedlots.

Daily cost of damage by granivorous birds was calculated using the following equation:

Cost of damage = N x DI x PM x V (after Folk & Kožená 1982)

Where N is the number of birds eating maize, DI is the daily food intake (grams per bird converted to kilograms), PM is the proportion of diet comprised of crushed maize and V is the value of maize consumed (Rands per kilogram). The price of crushed maize used in the estimates was standardised at the 1999 value of R 1.30 per kilogram (Phoenix Roller Mills, Grahamstown), but this would have varied depending on the district and on whether farmers grew and crushed their own maize. Only the most important groups of birds (numerically or in terms of daily consumption) were included in the damage estimates.

Male and female quelea appear identical in the non-breeding season when most damage occurs and dietary differences are negligible over this period (Ward 1965; Erickson 1984, in Erickson 1989). Average dietary data were therefore used to produce a single damage estimate for both sexes. Quelea commonly form mixed flocks with a variety of species including Red Bishops, Cape Sparrows and Masked Weavers which appear similar at a distance and which may have been included in the quelea population counts. These birds rarely exceeded 2% of the flock when it was possible to distinguish them and are thus unlikely to have affected damage estimates. Furthermore the higher daily consumption of Masked Weavers (this chapter) is likely to be compensated for by the lower proportion of maize in their diet.

6.2.2 Transect counts.

Granivorous birds were counted monthly by walking and driving along set transects through the feedlots. Additional details are provided in section 4.2.1 of Chapter 4.

6.2.3 Measurement of daily consumption of crushed maize by captive birds.

Because of the importance of flocking behaviour in locating good food sources in quelea (Craig 1989a), groups of birds rather than individuals were initially used to ensure that results of feeding trials would be more relevant to natural conditions. In addition, there are marked differences between the behaviour, at least in response to predators (Lazarus 1979), of solitary quelea and groups of several birds. However, differences were not significant between groups of two to four birds and larger. Groups of five quelea were therefore initially used in each trial. It was subsequently found that there was little difference between the feeding of solitary quelea and small groups in captivity and thus individuals were used in later experiments.

Quelea for all laboratory experiments were captured using mistnets on the farms Celva (32° 37' S; 25° 50' E) near Somerset East, Riverside Farm, Katkop and Lowlands Estate between 1996 and 1999 and were housed in an outdoor aviary (5.0 x 2.7 x 2.0 m) at the Department of Zoology and Entomology, Rhodes University, Grahamstown. They were provided with a shelter containing perches and were fed mixed birdseed (mainly millet *Panicum miliaceum* and manna *Setaria italica*) in excess of daily requirements. Water and gravel was available *ad libitum*. Birds were given one month to acclimate to cage conditions before experiments were started. Approximately one week prior to experiments, quelea were removed from the large aviary and weighed, checked for moult and colour ringed before being placed singly or in groups of five into a series of smaller outdoor (3.0 x 1.0 x 1.5 m) or indoor (1.5 x 0.75 x 1.0 m) cages to acclimate further.

Cape Sparrows and Masked Weavers were captured at Resolution Hatchery (33° 10' S; 26° 37' E), Rock Pigeons and Laughing Doves were caught in Grahamstown and Red Bishops and Wattled Starlings *Creatophora cinerea* were mistnetted at Katkop and Riverside Farm respectively. Birds were initially housed in conspecific groups in outdoor cages, but approximately one week prior to experiments they were each placed in separate cages to acclimate further.

Weavers, Red Bishops and sparrows were fed mixed birdseed while Laughing Doves and Rock Pigeons were provided with crushed maize. Wattled Starlings were fed mainly PRONUTRO® (a commercial breakfast cereal manufactured by National Brands Limited) and crushed maize, but since they are essentially fruit and insect eaters, fresh fruit (apples and grapes) was provided daily with occasional mealworms (Tenebrionidae). All species were given water and gravel *ad libitum.*

All birds were fed crushed maize for at least two days prior to measurement of daily consumption. Preliminary experiments in summer with groups of five birds showed that quelea, Red Bishops and Masked Weavers required a short (two day) adjustment period following the change to a purely maize diet after which consumption levels returned to normal. This may be related to the need to modify an existing search image. Measurements of normal daily consumption of maize for each group were used to calculate a mean value for each species. Winter measurements for all species were made with individually caged birds. No summer measurements were made with Laughing Doves, Rock Pigeons or Wattled Starlings so winter values were used in all calculations and may slightly over-estimate levels of consumption. The lower summer consumption estimates were used to assess quelea damage between December and March.

6.2.4 Analysis of the diet of birds utilising the feedlots.

Only birds feeding at the feedlots were of interest in this study so samples were collected from birds flying between feeding sites and day roosts within the feedlot complex. Quelea and Laughing Doves were the most important species utilising the ostrich feedlots and following two preliminary collections of quelea at Riverside Farm in October and November 1996, quelea and Laughing Doves were sampled monthly at Riverside Farm and Katkop between July 1997 and June 1999. Birds used in the damage estimates were all trapped at the ostrich feedlots, but after crushed maize was removed from the ostrich ration at Katkop samples of birds were still required to assess diet and trapping was therefore extended to include the cattle feedlot at Katkop (May-June 1998), then the ostrich feedlot at Lowlands Estate (September 1998-February 1999) and finally the Dairy at Katkop (March-July 1999).

Quelea, sparrows, weavers and doves were the main birds caught at Brandeston between July 1997 and June 1998, but since they fed mainly in and around the maize crushing shed, data could not be used to assess feed losses from the nearby ostrich feedlot. Samples of various other bird species regularly observed in the ostrich pens were occasionally collected to determine whether they were also actively feeding on crushed maize. Most birds were caught using mistnets and were killed with chloroform, but the farm manager shot species that were difficult to trap (e.g. Rock Pigeons and Wattled Starlings). Occasionally samples of other species were also supplemented in this way. Sample sizes varied depending on catching success.

Birds were kept on ice during the collecting trip and frozen on return to the laboratory until their gut contents were removed. Once dissected out, the gut contents were rinsed with water to remove blood and allowed to dry on filter paper at room temperature for approximately three days (Ward 1965). Crop and gizzard contents for each individual were sorted under a dissecting microscope and weighed to 0.01 g on an electronic balance. All insects were identified to order or family where possible. The various seed types were initially given code numbers and important species were later identified by comparison with seeds collected at the study sites, and using the reference seed collection of the Albany Museum Herbarium, Grahamstown.

The mean proportion of maize in the diet was assessed on a seasonal basis for quelea and Laughing Doves. Sample sizes for other species were too small to determine any seasonal trends but, since birds were collected over several months, they were sufficient to produce a rough annual measure of the relative importance of various food types. Rock Pigeons and Wattled Starlings were sampled mainly when they were present in greatest numbers and thus maize consumption values for these species are accurate for major damage periods.

The gravel component of the gut sample was excluded from any analysis and data were presented as mean percentages of the total dry organic mass rather than of the total gut or crop mass. Grass and weed seeds and insects comprised only a relatively small proportion of the total intake (by mass) of quelea in all seasons. The relative importance of these different food items was therefore also assessed according to the percentage of birds of the total sample for each site that had eaten them (after Lourens 1963). Because of the difficulty in identifying grass seeds, priority was given to those species that appeared to be important in the diets of these birds, i.e. were eaten by more than 10% of individuals or comprised a large proportion (10% or more) of the total organic mass, were identified. Birds with empty crops and gizzards were excluded from the analysis.

6.2.5 Economic analysis of bird damage (comparison of the monthly cost of maize lost to problem birds with overall monthly running costs and profits of the ostrich feedlot).

Following the slump in the market for ostrich products in the late 1990s the value of slaughter birds dropped dramatically. At this time the skin of an ostrich accounted for 70% of the value of the bird. Since tanneries prefer a 14-month-old skin (Caryer 1996), it was assumed that most ostriches are slaughtered at around this age. The value of a slaughter ostrich varies considerably according to, among other things, the quality of its skin and for the purposes of this analysis an estimated average of R 1000 per bird (A. Roets, pers comm.) was used. The ostrich market remained depressed throughout this study and while running costs increased, there was no corresponding increase in the value of slaughter birds.

Production costs were estimated from data provided in the East Cape Ostrich Producers Association (ECOPA) newsletter, January/February 1997 and assumed an average annual producer inflation of 7.0% (Broodryk 1998). For the purposes of this analysis it was also assumed that an ostrich ate the same quantity of food, two kilograms per day (M. Collett, pers. comm.), throughout the 14-month rearing period. This overestimates the feeding costs of young birds, but is likely to be balanced by the greater labour, heating and medical costs as well as the higher mortality of young birds that are not accounted for elsewhere.

Table 6.1 Estimated cost of rearing an ostrich to slaughter age (14 months) in an Eastern Cape feedlot in 1997, 1998 and 1999.

Costs	1997	1998	1999
Cost per chick	R 275.00	R 275.00	R 275.00
Feed (Crushed maize and Lucerne mix)	R 420.00	R 449.40	R 480.86
	(R 0.50 per kg)	(R 0.54 per kg)	(R 0.58 per kg)
Travel (excluding transport to abattoir)	R 39.20	R 41.94	R 44.88
Labour	R 70.00	R 74.90	R 80.14
Total cost	R 804.20	R 841.24	R 880.88
Income per ostrich	R 1000.00	R 1000.00	R 1000.00
Profit per ostrich	R 195.80	R 158.76	R 119.12

Between June and December 1998, ostriches at the Katkop feedlots were fed whole maize (R 1.00 per kg) rather than crushed maize (R 1.30 per kg) in their feed ration. Consequently the estimated cost per kilogram of the mixed ration dropped to R 0.46. This effectively reduced the cost of feeding each ostrich by R 4.50 per month and R 63.00 over a 14-month period.

The total cost presented in Table 6.1 should be considered a minimum estimate. The loss of livestock and incidental expenditures such as maintenance of pens, veterinary bills and medicines are difficult to predict and have therefore not been included. These and other hidden costs such as the initial construction of infrastructure (e.g. R 1700 for a quarter hectare pen in 1997) and the purchase of vehicles and equipment also reduce the final profit margin.

6.3 RESULTS

6.3.1 Birds observed eating crushed maize at the feedlots.

A wide variety of bird species was recorded at the Brandeston, Riverside Farm and Katkop feedlots over the study period, but only a small proportion of these were observed feeding on crushed maize in the livestock ration (Table 6.2).

Table 6.2 Granivorous bird species that were observed eating crushed maize at the Brandeston, Riverside Farm and Katkop ostrich feedlots.

Species	Location		
	Brandeston	Riverside Farm	Katkop
Red-billed Quelea	x	x	x
Red Bishop	x	x	x
Cape Sparrow	x	x	x
Grey-headed Sparrow	x	x	x
House Sparrow	x	x	x
Masked Weaver	x	x	x
Spotted-backed Weaver	x		
Rock Pigeon	x	x	x
Laughing Dove	x	x	x
Red-eyed Dove	x	x	x
Cape Turtle Dove	x		
Namaqua Dove		x	x
Wattled Starling	x	x	x
Pied Starling	x	x	x
Black Widowfinch	x		
Red-billed Firefinch	x		

Monthly variations in the numbers of the most important potential pest species recorded at each of the ostrich feedlots are shown in Appendices 4-6. The remaining species listed in Table 6.2 were only occasionally recorded at the feedlots or occurred in relatively small numbers and were considered to be of little concern.

Due to the unpredictable composition of the ostrich ration at Brandeston (Chapter 2), seasonal trends in the number of birds observed at the feedlot (Appendix 4) were difficult to relate to the dependence of these bird species on the crushed maize. Numbers of most species were quite variable between months suggesting mobility of flocks and opportunistic utilisation of suitable food sources when they were available. Sparrows, which appeared to be less dependent on the crushed maize, were more abundant in autumn and winter even after maize was removed from the ration. Numbers of Laughing Doves and Red-eyed Doves *Streptopelia semitorquata* remained relatively low after the grain component of the ostrich feed (either maize or barley) was removed.

Quelea were by far the most abundant bird species at the Riverside Farm ostrich feedlot (Appendix 5). Their numbers were only exceeded by other species in late summer and early autumn when the majority of quelea departed the feedlots in full breeding plumage (after December 1997 and after January 1999). No successful quelea breeding (eggs or chicks in nests) was recorded at Riverside Farm and these departing birds were suspected to be breeding away from the farm. Numbers of Rock Pigeons at the feedlots were variable, but they were generally more abundant during the spring and summer than in the dry winter months. Numbers of Laughing Doves remained relatively constant and although large numbers (more than 300) were occasionally recorded (October 1997, January 1998, January 1999 and May 1999), this appeared to be independent of season. Pied Starlings *Spreo bicolor* were observed on each visit to the Riverside Farm, but numbers varied considerably between months. This may partly be attributed to the wide range of suitable feeding habitats available to this omnivorous species in a mixed farming environment (crop lands, fallow fields, feedlots, road verges, and natural bush). Wattled Starlings were considerably more seasonal and were rarely observed in the feedlots during the wet summer months.

Quelea and Laughing Doves were observed in the Katkop ostrich feedlot in almost all months (Appendix 6), albeit in lower numbers after the removal of first the crushed maize (April 1998) and later the whole maize (November 1998) components from the ostrich ration. Numbers of Rock Pigeons, Wattled Starlings and Pied Starlings were generally low, these species preferring to feed in the surrounding cultivated fields when they were present in the area.

Small numbers of Namaqua doves *Oena capensis*, Cape Turtle Doves *Streptopelia capicola*, Red-eyed Doves and Red-billed Firefinches *Lagonosticta senegala* were commonly recorded at all three study sites, but were rarely seen eating the ostrich ration. Black Widowfinches *Vidua funerea* were recorded at both Brandeston and Riverside Farm, though usually away from the feedlots. Spotted-backed Weavers *Ploceus cucullatus* do not occur in Cookhouse or Fish River, but were commonly found at the Brandeston feedlots and at feedlots throughout the surrounding Albany District

6.3.2 Measurement of daily consumption of crushed maize.

Quelea caged in groups of five consumed slightly more than individually caged birds (Table 6.3), but these differences were not significant (ANOVA, P=0.608). Quelea and Red Bishops increased daily consumption by about 40-50% between summer and winter while Masked Weavers showed a 35% increase over the same period. These significant (ANOVA, P<0.001) increases in consumption in winter were presumably due to increased thermoregulatory costs that are likely to be greater for smaller species.

Table 6.3 Mean mass (g ± standard deviation) and mean daily consumption (g ± standard deviation) of crushed maize by individually caged captive birds. Mean mass values are for a random sample of birds caught at various Eastern Cape feedlots. The second winter estimate for quelea was for groups of five birds.

Species	Mass	n	Daily consumption			
			Summer	n	Winter	n
Cape Sparrow	24.3 ± 1.6	20			4.3 ± 1.2	9
Masked Weaver	30.0 ± 4.1	20	4.82 ± 0.29	4	6.53 ± 0.59	9
Quelea	18.0 ± 1.2	20	2.99 ± 0.45	10	4.45 ± 0.59	10
Quelea					4.60 ± 0.59	13
Red Bishop	21.4 ± 2.3	20	3.01 ± 0.58*	10	4.61 ± 0.61	6
Rock Pigeon	319.8 ± 33.5	11			23.55 ± 6.07	11
Laughing Dove	95.7 ± 8.0	20			12.17 ± 2.59	10
Wattled Starling	78.4 ± 7.2	20			13.21 ± 5.54	6

* From Ludick 1997

Rock Pigeons, the largest species, had the highest mean daily consumption, but other species did not necessarily rank as expected from their mass. Wattled Starlings ate more than the heavier Laughing Doves and this may be related to differences in gut anatomy. Quelea consumed the same amount in winter as the larger Red Bishop and both consumed more than the Cape Sparrows, the largest of the three species. While this observation may be attributed to differences in metabolic rate of the three species, it may also reflect differences in the extent to which the different species acclimated to cage conditions and the crushed maize food. Acclimation to crushed maize may well have been influenced by the seasonal importance of this food in the diet of each species at the feedlots where they were collected.

6.3.3 Analysis of the diet of birds utilizing the feedlots.

Not all birds would have fed exclusively in and around the feedlots where they were collected. However, on most visits, birds ringed several hours earlier were recaptured in the same or nearby nets (less than 1 km away). Thus at least a proportion of the bird population at the feedlots appears to be relatively sedentary on a given day. This observation combined with the fact that many day roosts were located in the vicinity of the feedlots and that the only large-scale movements of flocks into and out of the feedlots occurred in the early morning and at dusk respectively, suggests that there was not a high turnover among birds feeding in a given area. When crushed maize was present in the ostrich ration it was available throughout the day, and while there were movements among nearby feedlots, between feedlots and surrounding fields, and *vice versa,* these occurred randomly through the day. It is therefore considered likely that the proportion of maize in the diet of these birds is a good reflection of their dependence on this artificial food source.

Brandeston.

Maize was one of the most important food items in the diet of all species collected at Brandeston (Table 6.4). Cape Sparrows were least dependant on maize, and instead grass and weed seeds comprised the bulk of their diet. Grass and weed seeds were also important in the diet of Laughing Doves, Grey-headed Sparrows and quelea, but to a much lesser extent. Only Masked and Spotted-backed Weavers consumed insects to any great extent. When crushed maize was removed from the ostrich ration after February 1998, all species increased their relative consumption of natural seeds. Seeds exceeded 94% of the diet of all species in March 1998 except Spotted-backed Weavers that ate, on average, 59% insects and only 41% seeds.

Table 6.4 Analysis of the diets of granivorous species at the Brandeston feedlots between July 1997 and February 1998 when maize was included in the ostrich ration. Values represent mean percentage of the dry organic component of the diet with standard deviation.

Species	n	Maize	Seed	Unidentified plant matter	Animal matter
Cape Sparrow	21	34.3 ± 40.2	61.4 ± 39.6	2.3 ± 26.8	2.0 ± 6.5
Grey-headed Sparrow	28	47.6 ± 41.7	38.6 ± 37.5	10.1 ± 31.5	4.8 ± 8.9
Laughing Dove	1	56.4 ± 36.7	31.3 ± 32.3	9.9 ± 19.8	2.4 ± 14.1
Masked Weaver	22	54.1 ± 45.3	6.0 ± 16.8	21.6 ± 34.2	18.3 ± 26.8
Spotted-backed Weaver	36	60.5 ± 41.4	7.2 ± 16.1	11.4 ± 29.6	20.9 ± 27.5
Quelea	24	46.8 ± 44.5	20.3 ± 31.3	28.1 ± 41.2	4.8 ± 11.9

Seven of the 13 grass and weed species eaten by quelea at Brandeston appeared in more than 10% of samples (Appendix 7). These included Type 22 (33.4%) *Echinochloa* sp. (33.4%), Type 21 (25.1%), *Urochloa panicoides* (25%), Type 26 (20.8%), and a species tentatively identified as a *Sporobolus* sp. (16.7%). The ubiquitous *Amaranthus* and *Chenopodium* spp. were very difficult to distinguish and separate in samples and were therefore grouped together and treated as a single species in all analyses. They were eaten by 16.7% of the quelea sampled. Altogether these seven species comprised approximately 95% of the non-maize seed mass consumed by quelea at Brandeston.

Seeds of *Amaranthus* and *Chenopodium* spp. and *Acacia karroo* comprised the bulk (79.4% by mass) of the non-maize seed component of the diet of Laughing Doves at Brandeston. A further five species occurred in more than 10% of samples including Type 28 (31.7%), *Echinochloa* spp. (14.6%), *Solanum* sp. (14.6%), Type 6 (12.2%) and the seeds of the invasive Queen of the Night cactus *Cereus jamacaru* (12.2%). Although the doves were never seen feeding directly from the cactus, fallen fruit was abundantly available on the ground for several months each year. Altogether, Laughing Doves at Brandeston ate seeds of 28 different grass and weed species.

Red-eyed Doves, Cape Turtle Doves, House Sparrows, Red Bishops, Pied Starlings and Red-billed Firefinches occurred in relatively small numbers at Brandeston over most of the sampling period. The gut contents of four House Sparrows, two Red-eyed Doves and one each for the remaining species were examined. Maize was the main food item in all except the Pied Starling, that had eaten seeds and insects, and the Red Bishop, that may have been feeding chicks and only had insects in its gut.

Riverside Farm.

Maize was the main component in the diet of all species at Riverside Farm except Masked Weavers that ate predominantly insects (Table 6.5). Insects also made up a large proportion of the diet of Pied Starlings (22.8%), but comprised less than 10% of the mean annual diet of all other species that appeared to be mainly granivorous. Intra-specific variability was high, even among monthly samples, with some birds in the population eating only maize and others only grass and weed seeds. Seeds of the Devil's Thorn *Tribulus terrestris*, the grass *Urochloa panicoides* and wheat *Triticum* sp. formed the bulk of the remaining vegetable component in the diet of Rock Pigeons, while the animal component included fly pupae, termites, small snails, pieces of eggshell and tiny bones.

Table 6.5 Analysis of the diets of granivorous species at the Riverside Farm feedlot (October - November 1996 and July 1997 - June 1999). Values represent mean percentage of the dry organic component of the diet with standard deviation.

Species	n	Maize	Seed	Unidentified plant matter	Animal matter
Quelea	320	81.5 ± 34.3	15.0 ± 31.5	1.0 ± 8.3	2.5 ± 8.6
Red Bishop	23	64.4 ± 43.0	9.1 ± 21.4	19.6 ± 34.2	6.9 ± 15.2
Laughing Dove	102	69.8 ± 35.8	25.1 ± 33.0	5.0 ± 16.6	0.1 ± 0.3
Rock Pigeon	16	85.3 ± 20.1	4.6 ± 5.6	7.4 ± 19.6	2.7 ± 0.4
Wattled Starling	34	82.7 ± 28.4	7.3 ± 19.4	4.4 ± 11.5	5.6 ± 19.2
Masked Weaver	10	29.8 ± 42.7	5.7 ± 9.9	15.8 ± 23.9	48.7 ± 39.3
Pied Starling	7	56.5 ± 46.2	20.0 ± 23.9	0.7 ± 1.5	22.8 ± 34.5

Three gut contents each of Cape Sparrows, Grey-headed Sparrows and Namaqua Doves and two of Cape Turtle Doves were also examined. Maize comprised 60-70% of the diet of these birds while the remainder was mainly seeds with less than 2% animal matter.

Katkop and Lowlands Estate.

Maize once again comprised the bulk of the diets of most birds collected at feedlots in the Fish River area (Table 6.6). Insects constituted 24% of the diet of Masked

Weavers, but various seeds accounted for much of the remaining food eaten by all other species.

Table 6.6 Analysis of the diets of granivorous species at the Katkop/Lowlands Estate feedlots (July 1997 - June 1999). Values represent mean percentage of the dry organic component of the diet with standard deviation.

Species	n	Maize	Seed	Unidentified plant matter	Animal matter
Quelea	283	68.9 ± 40.8	24.9 ± 37.4	3.2 ± 15.3	3.0 ± 12.7
Red Bishop	47	58.5 ± 41.0	26.1 ± 34.4	13.2 ± 27.6	2.2 ± 7.8
Laughing Dove	80	61.9 ± 40.7	20.4 ± 29.8	17.0 ± 32.7	0.7 ± 3.2
Masked Weaver	10	54.2 ± 46.6	3.2 ± 5.4	18.6 ± 32.3	24.0 ± 35.0
Pied Starling	10	46.3 ± 41.1	41.6 ± 36.3	0.9 ± 2.4	11.2 ± 17.9

Seeds of *Atriplex semibaccata* and *Solanum* sp. comprised the bulk of the vegetable component in diet of Pied Starlings collected at both Riverside Farm and Katkop/Lowlands Estate while beetles (Chrysomelidae and Curculionidae) and ants (Formicidae) were the most important insects. Wattled Starlings ate more beetles from a range of families (Carabidae, Chrysomelidae, Curculionidae, Cerambycidae and Scarabaeidae), but also ate ants, termites (Isoptera), caterpillars (Lepidoptera) and grasshoppers (Orthoptera). Various unidentified fruits comprised the main non-maize component of their diet, but seeds of *Atriplex semibaccata, Urochloa panicoides,* Devil's Thorn and wheat were also eaten.

6.3.4 Seasonal changes in the diet of quelea.

Riverside Farm.

The mean percentage of crushed maize in the diet of quelea at Riverside Farm, relative to other food items, was high (above 60%) throughout the year with a peak of around 90% in each winter and spring (Figure 6.1). Some individuals fed exclusively on maize in all seasons, but the relatively low standard deviations for mean winter and spring values (Appendix 8) suggest greatest dependence on maize during this period.

Highest consumption of grass and weed seeds was found in summer and autumn (18-29%) following the spring rains. In total, 24 different species were eaten with a maximum of 12 recorded in any one season. Of these, *Echinochloa* spp. (14.1%), *Urochloa panicoides* 13.4%), *Amaranthus* and *Chenopodium* spp. (9.1%) and *Panicum* sp. (7.8%) appeared to be most important in terms of the number of individuals that ate them (Appendix 7). The bulk of the mass of grass and weed seeds eaten by these birds was comprised of mainly four species *Echinochloa* spp. (32.3%), *Urochloa panicoides* (22.8%), *Panicum* sp. (18.2) and wheat (16.7%). The *Amaranthus* and *Chenopodium* spp. seeds were eaten by many quelea, but due to their small size they did not contribute much to the overall mass of seeds eaten. In contrast the much larger wheat seeds were eaten by only 2.2% of quelea, yet these contributed substantially to the overall weight of the non-maize vegetable component. The remaining three species, *Echinochloa* spp., *Urochloa panicoides* and *Panicum sp.*, ranked in the same order by number of individuals that ate them and by weight (Appendix 7).

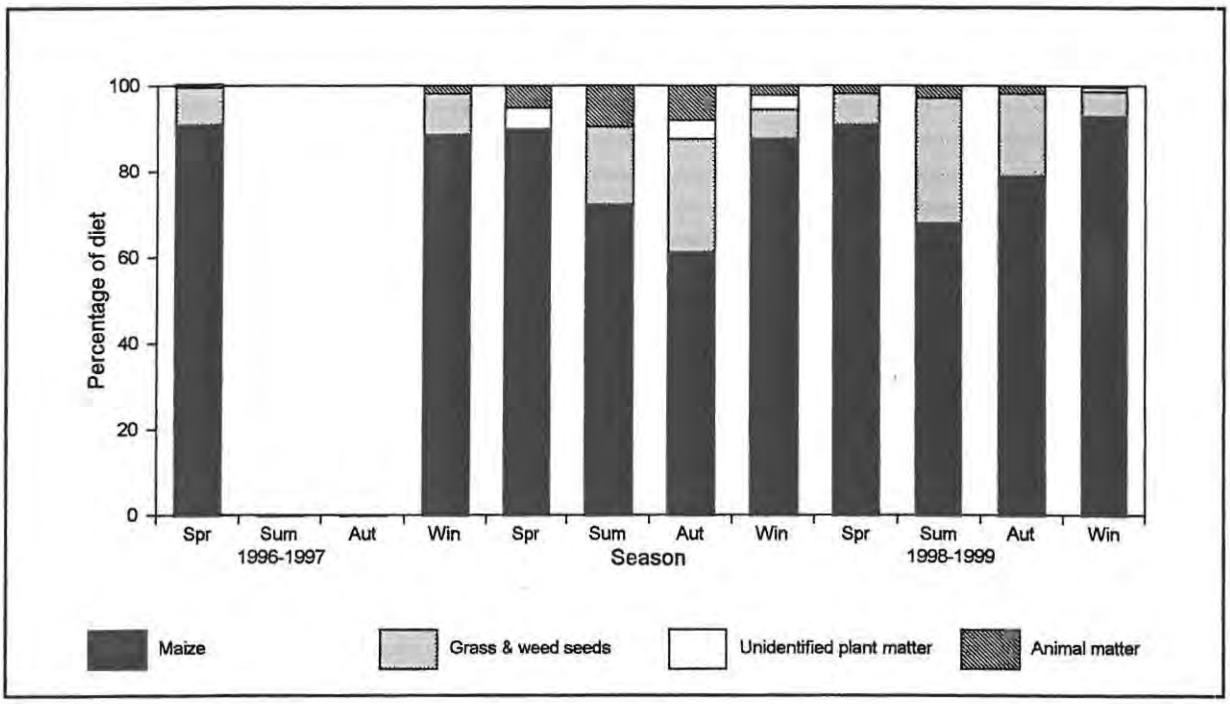


Figure 6.1 Seasonal changes in the diet of quelea captured at Riverside Farm between spring 1996 and winter 1999. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug). No data were collected in summer 1996-1997 and autumn 1997. (For actual values see Appendix 8).

Insects comprised only a small proportion of the diet of quelea throughout the year, but consumption peaked between spring 1997 and autumn 1998, possibly in relation to breeding. Termites appeared to be the most important insect food and, although only found in 10% of samples, they comprised 96% and 98% by mass of all animal matter consumed in spring 1997 and autumn 1998 respectively. Ants were only eaten by 2%

of the quelea sampled yet they comprised 98.5% of the mass of animal matter consumed by all quelea in summer 1997-1998. Beetles (mainly Curculionidae and Chrysomelidae) were found in 7% of samples, caterpillars (Noctuidae) in 2% and spiders, grasshopper nymphs (Acrididae), wasps (Hymenoptera), flies (Diptera) and various bugs (Hemiptera) were each found in only 1% of samples. One piece of snail shell was the only non-arthropod animal component.

Katkop and Lowlands Estate.

Maize was one of the most important constituents in the diet of quelea in all seasons at Katkop and Lowlands Estate (Figure 6.2) but, as at Riverside Farm, dependence on maize was generally greatest in winter and spring and comprised as much as 98.6 % of intake in spring 1998. Following the spring rains, natural seeds became considerably more important in the diet of quelea and were consumed in similar proportions to maize in summer and autumn. Dependence on maize was lowest in autumn.

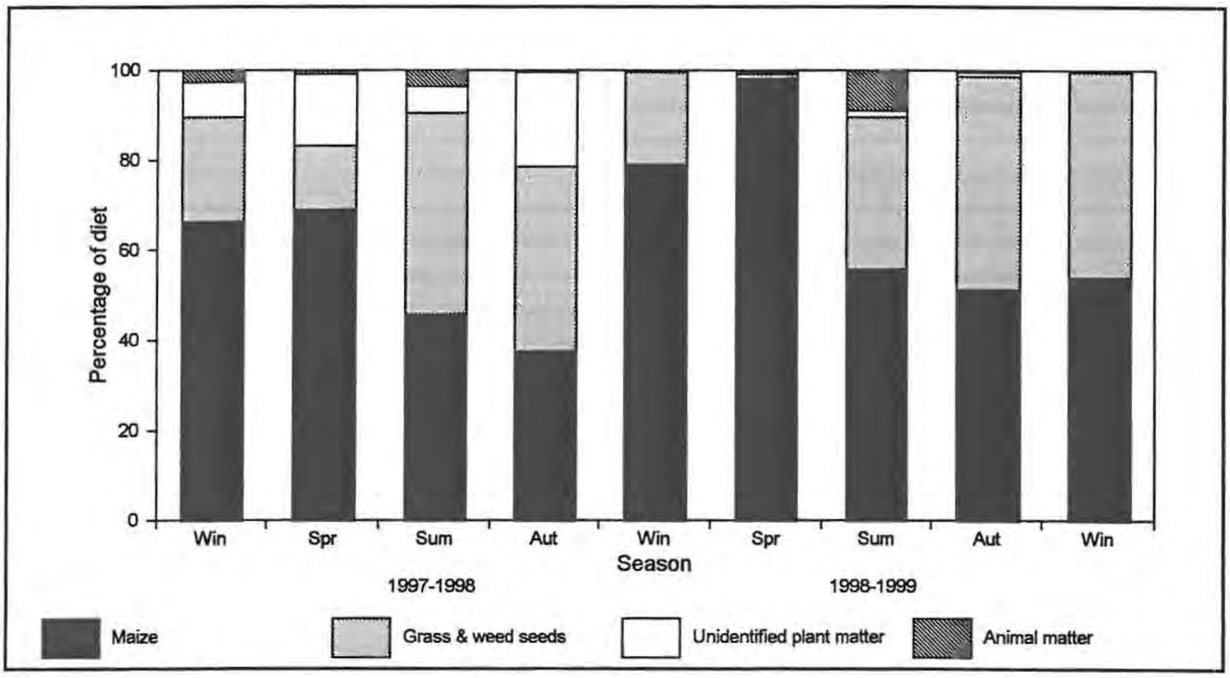


Figure 6.2 Seasonal changes in the diet of quelea captured at feedlots in the Fish River area between winter 1997 and winter 1999. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug). (For actual values see Appendix 9).

Quelea utilised 27 different grass and weed species over the study period with a maximum diversity of 14 in one season and a minimum of four. There was no consistent trend with regard to time of year. A wider range of grass and weed species were eaten by quelea at Katkop/Lowlands Estate than at Riverside Farm, but only four of these appeared to be important (Appendix 7). *Urochloa panicoides, Panicum* sp., *Amaranthus* and *Chenopodium* spp. and *Echinochloa* spp. were again the dominant species occurring in 21.6, 13.4, 12.7 and 12.4% of the samples respectively and comprising 23.1, 31.1, 2.9 and 13.1% of the non-maize seed mass. An unidentified grass seed, Type 2, was found in only 8.8% of samples, but comprised 15.6% of the seed mass eaten by quelea sampled at this site. Ranking seeds according to the percentage of individuals that ate them and the mass of seeds consumed produced a different order of relative importance.

Animal matter remained below 10% of the mean intake of quelea at Katkop/Lowlands Estate throughout the year and was most important in their diet in summer, possibly in relation to breeding. Although they were only found in 5% of gut samples, Curculionid beetles and ants were the most widely consumed insects and comprised the bulk of the animal component. Indeed, winged ants comprised 95% by weight of all animal matter eaten in summer 1998-1999. Termites were eaten by 4% of quelea and bugs, predominantly Cicadellidae, and wasps were found in 2% of those sampled. Caterpillars and flies were found in less than 1% of samples. Tiny snails were only eaten by one of the sampled quelea (a male), but at least 14 individuals of several different species could be distinguished. Shell fragments from a larger snail were found in one other quelea.

6.3.5 Seasonal changes in the diet of Laughing Doves.

Riverside Farm.

At Riverside Farm, maize was the most important food item for Laughing Doves in all seasons (Figure 6.3). Although sample sizes were low, it appears that dependence on maize was greatest in winter (79-99%). Consumption of maize dropped approximately 30% between winter and spring in 1997 and approximately 39% between winter 1998 and summer 1998-99 (Appendix 10), presumably as natural seeds became more abundant. Better than average spring rains in 1998 (Chapter 2) and a good weed and grass crop may account for the increased importance of natural seed in the diet of Laughing Doves in 1999.

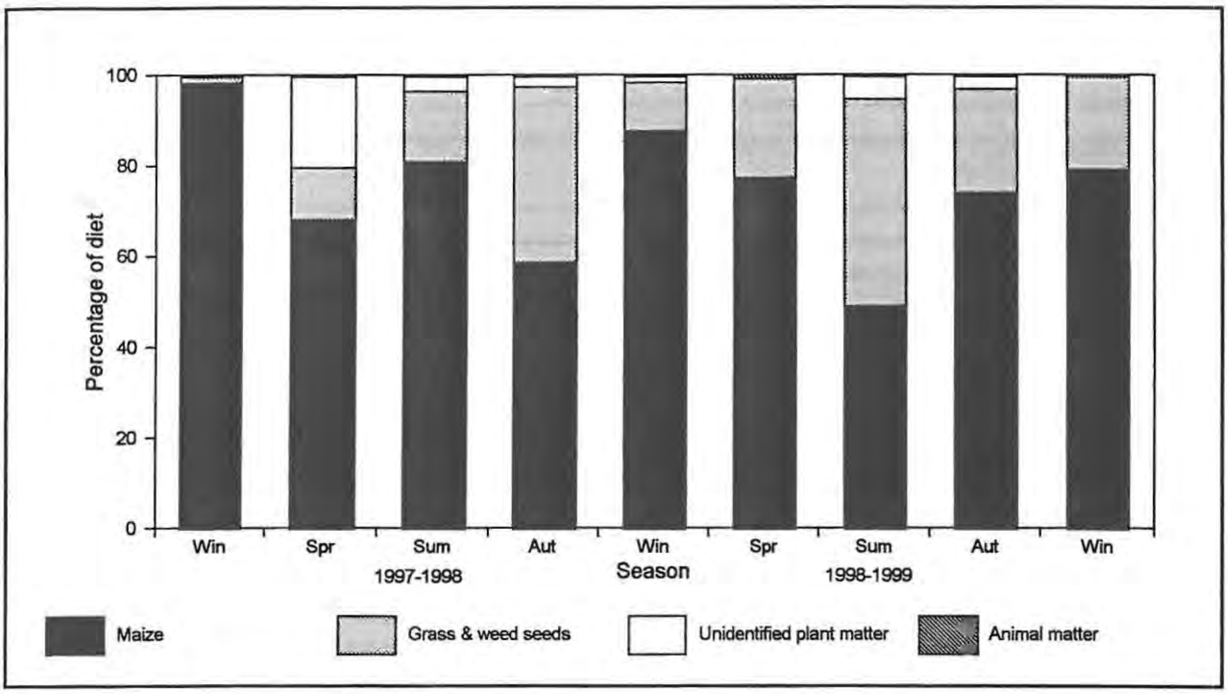


Figure 6.3 Seasonal changes in the diet of Laughing Doves captured at Riverside Farm between winter 1997 and winter 1999. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug). (For actual values see Appendix 10).

Although Laughing Doves utilised a considerably wider variety of grass, weed and fruit species than quelea at both sites (45 in total), only six of these were eaten by more than 10% of birds sampled. *Amaranthus* and *Chenopodium* spp., *Urochloa panicoides*, *Echinochloa* spp., wheat, *Solanum* sp., Type 28 and *Rhus* sp. were found in 64.7, 25.5, 14.7, 11.8, 11.8,11.8 and 9.8% respectively of the guts examined (Appendix 7). *Amaranthus* and *Chenopodium* spp. and *Urochloa panicoides* were eaten in all seasons with the former comprising just over half (52.1%) of the total non-maize seed mass eaten by Laughing Doves at Riverside Farm. Devil's Thorn *Atriplex semibaccata*, and *Acacia karroo* seeds were eaten by fewer than 10% of doves, but were the largest seeds after maize. Wheat appeared in the diet of doves from spring 1998 to winter 1999, but for the most part this was probably waste grain remaining after the harvest in December 1998. It nevertheless comprised 24.2% of the total non-maize seed mass eaten by Laughing Doves, and was the only seed other than *Amaranthus* and *Chenopodium* spp. to exceed 10%. Diversity of seeds in the diet of Laughing Doves was consistently lowest in winter (maximum of 9) of each year and highest in spring (maximum of 22), but this may be related to the sample size of doves collected.

Animal matter appeared to be of little importance in the diet of Laughing Doves and comprised less than 1% of mean consumption in all seasons. Larvae and pupae of the House Fly *Musca domestica* were abundant wherever ostrich feed and manure had collected, and were the most commonly utilised insect food, despite being eaten by only 4% of Laughing Doves. Termites, found in 2% of samples, were the only other insect food. Tiny snails were eaten by 3% of doves and pieces of eggshell were found in 5% of gut samples.

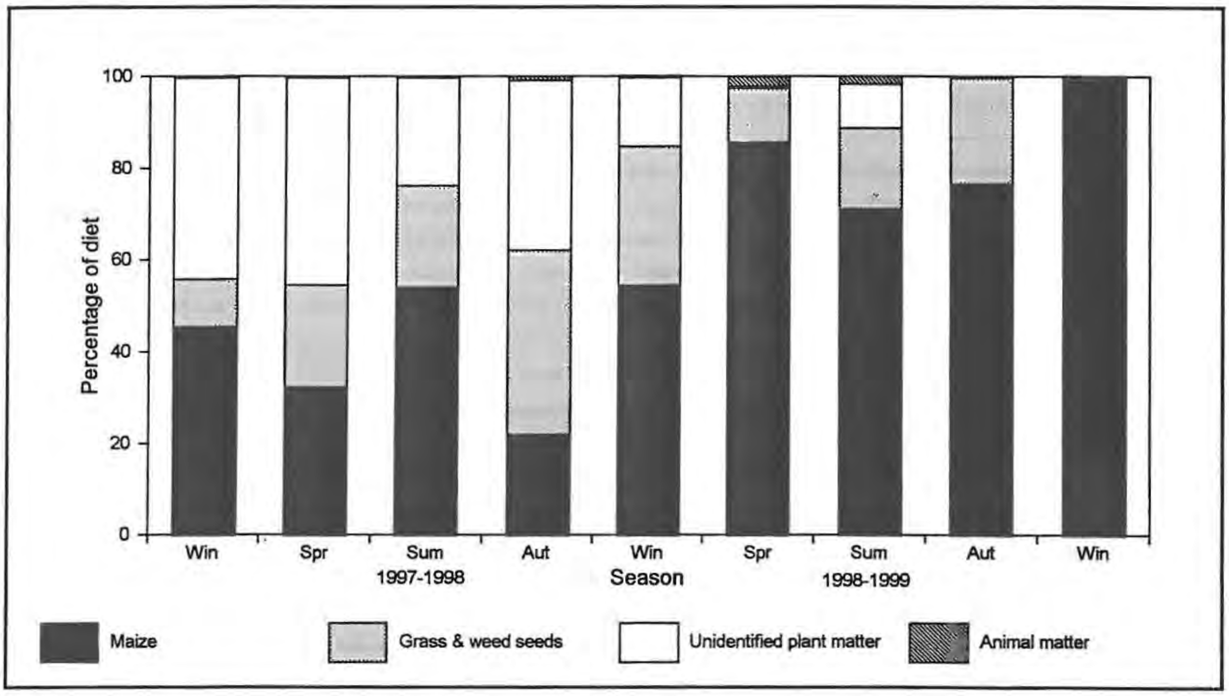


Figure 6.4 Seasonal changes in the diet of Laughing Doves captured at feedlots in the Fish River area between winter 1997 and winter 1999. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug). (For actual values see Appendix 11).

Seasonal patterns were less obvious in Laughing Doves in the Fish River area due to relatively small samples and a high proportion of unidentified plant matter (Figure 6.4). Maize consumption appeared to be relatively low throughout 1997 with a peak of 54.4 % in summer, but unidentified material accounted for almost half the sample in winter and spring when maize was most important to quelea. In 1998, consumption of maize was lowest in autumn and highest in spring (85.9%), following the same trend as quelea, and remained at a high level for the rest of the study period.

Laughing Doves at Katkop utilised 40 species of grass, weed and fruit seeds. Once again, the diet of the doves was considerably more diverse than that of quelea at the same locality, but similar to doves sampled at Riverside Farm. However, only seven of these species appeared in 10% or more of the Laughing Dove gut samples (Appendix 7). Diversity of seeds eaten was consistently lowest in winter (maximum of 3) and highest in summer (maximum of 23) with an increase in spring and a decrease in autumn. Seeds of *Amaranthus* and *Chenopodium* spp. were found in 70% of samples and comprised 75.3% of the total non-maize seed mass eaten by Laughing Doves at this site. Seeds of *Rumex crispus, Urochloa panicoides, Echinochloa* spp., *Atriplex semibaccata, Solanum* sp. and *Panicum* sp. were considerably less frequently eaten and occurred in only 25.0, 18.8, 13.8, 11.3,11.3 and 10.0% of samples respectively. None of these seeds comprised more than 10% of the total non-maize seed mass eaten.

Animal matter, once again, formed only a small proportion of the diet in all seasons. Tiny snails appeared to be the most commonly consumed item and were found in 13% of gut samples. Up to 21 snails were found in the crop of a single bird. Pupae and larvae of the House Fly were found in 9% of samples and ants in 4%. Caterpillars, beetles and pieces of eggshell were each found in 1% of samples.

6.3.6 Assessment of maize eaten by problem birds at the Riverside Farm and Katkop ostrich feedlots between July 1997 and June 1999.

Riverside Farm.

The total amount of maize removed from the Riverside Farm ostrich feedlot by quelea, Rock Pigeons, Laughing Doves and Wattled Starlings combined over the period July 1997 to June 1999 (excluding August 1997) was estimated at 13.5 tons with a market value of R 17 550 (Figure 6.5). Quelea were the biggest problem, accounting for over half the total losses (R 11 369). Wattled Starlings removed an estimated R 2 507 worth of crushed maize followed by Rock Pigeons and Laughing Doves with R 2021 and R 1585 respectively. Combined loss of maize was consistently highest in winter and early spring and lowest in summer when fewer ostriches were being fed and alternative "natural" food sources were available. The only reliable source of crushed maize at Riverside Farm in March and April 1999 was that fed to approximately 100 ostrich chicks.

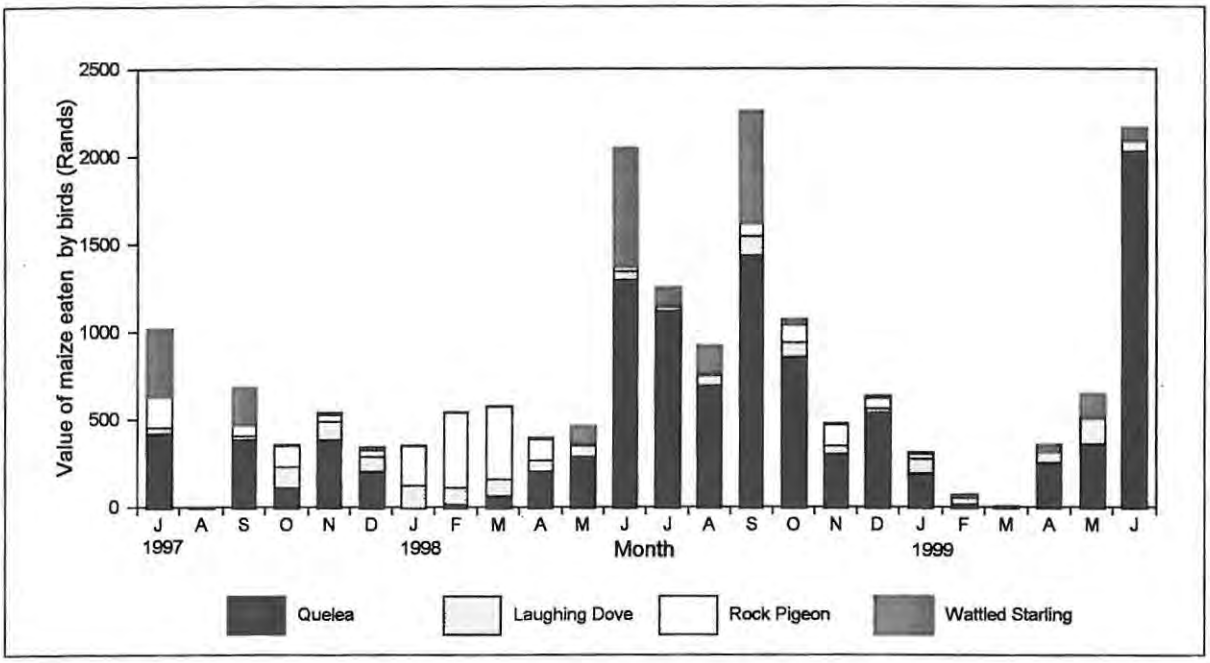


Figure 6.5 Estimated value of maize removed by granivorous bird species from the ostrich feedlot at Riverside Farm between July 1997 and June 1999. No data were obtained for August 1997.

Quelea were responsible for the majority of maize loss in all months except January-March 1998 when Rock Pigeons were present in large numbers and they consumed in excess of R 1000 worth of maize of the three month period. Consequently, the overall trend in feed loss through the study period tends to follow the population cycles and feeding behaviour of quelea closely. Rock Pigeons also fed on waste grains in the fields of maize stubble after the crop was harvested in February 1998, and this may have reduced their dependence on feedlot maize to an extent. After the fields of maize stubble were ploughed in late April, Rock Pigeons numbers in the feedlot dropped dramatically, but increased again after winter. They were seen feeding in the harvested wheat fields in December, but little food was available in the feedlot until the following winter and most Rock Pigeons had left the area by January 1999.

The proportion of maize in the diet of Laughing Doves was greatest over winter but, since their main influx to the Riverside Farm feedlot was generally in spring and summer (Appendix 5), losses to this species were predictably highest over this period. Most significant losses (R 140) were, however, recorded in May 1999 due to an uncharacteristically late influx of these birds.

Wattled Starlings were sporadic visitors to Riverside Farm throughout the year, but damage peaked at around R 650 per month in June and September 1998, following sudden influxes of these birds. A number of other species including Red Bishops, Masked Weavers, Namaqua Doves, Pied Starlings, Helmeted Guineafowl and various sparrows, canaries and firefinches also ate maize meant for the ostriches, but since they only occurred in small numbers, they were not thought to present a significant problem.

Katkop.

Quelea and Laughing Doves were the main species utilising the ostrich feedlot at Katkop. Due to the smaller size of this feedlot, the removal of crushed maize from the ostrich ration after April 1998, and the subsequent removal of all maize after November 1998, feed losses were considerably lower than at Riverside Farm. The total value of maize removed from the ostrich ration at Katkop between July 1997 and November 1998 was estimated at R 600 (Figure 6.6). These losses would have been considerably higher (in excess of R 2500 to quelea alone) had the amount of maize eaten by problem birds at the dairy and cattle feedlot been included in the assessment.

In contrast to observations at Riverside Farm, quelea consumed more maize at the Katkop ostrich feedlot during the spring and summer months than during the rest of the year. Laughing Doves were also most abundant at this time (as at Riverside Farm) and the value of maize losses to problem birds peaked at almost R 160 in November 1997. Quelea were again responsible for the greatest losses for most of the study period, but after January 1998 Laughing Doves consumed more maize. Replacement of crushed maize with whole kernels between June and November 1998 prevented small birds from feeding, but Laughing Dove damage followed the same trend as in 1997. Doves fed predominantly on waste maize in surrounding fields from harvest time in May until ploughing in August and September. After this, the number of doves in the feedlots increased until maize was removed from the ration in December.

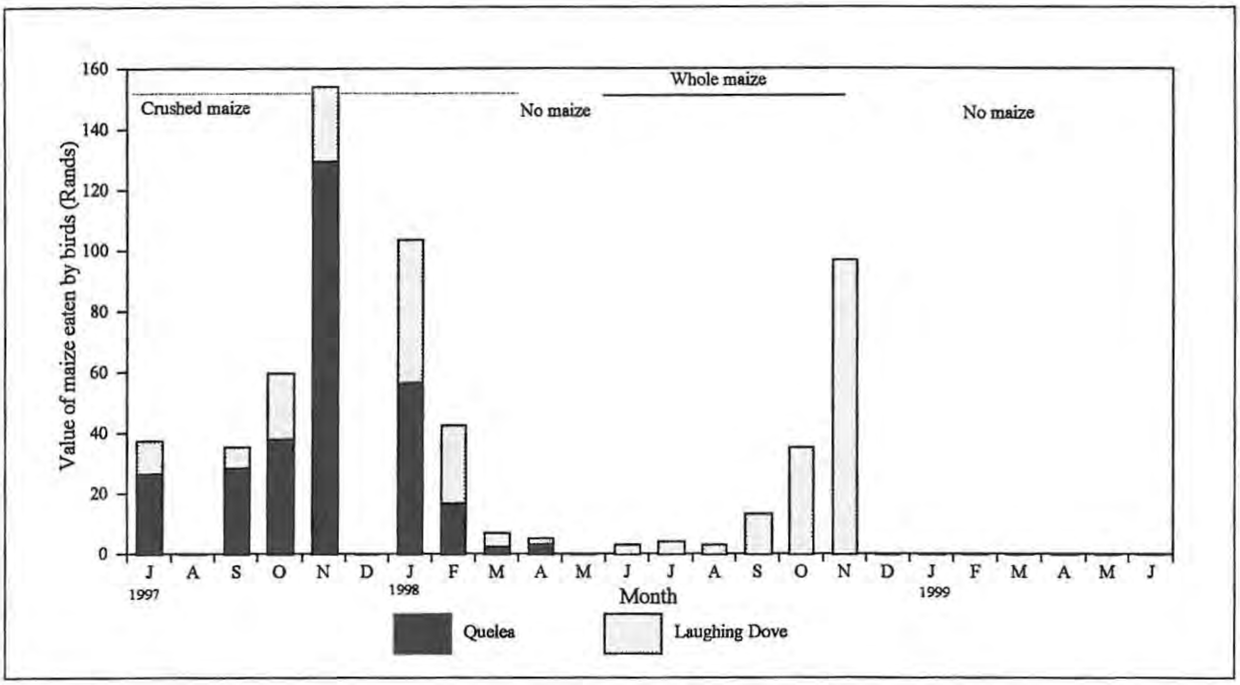


Figure 6.6 Estimated value of maize removed by granivorous bird species from the ostrich feedlot at Katkop between July 1997 and June 1999. No data were available for August and December 1997.

6.3.7 Economic analysis of bird damage (comparison of the monthly cost of maize lost to problem birds with overall monthly running costs and profits of the ostrich feedlot).

The estimated amounts of maize consumed by quelea, Laughing Doves, Rock Pigeons and Wattled Starlings were included in the economic analysis for Riverside Farm. The number of ostriches kept at Riverside Farm was only recorded during 1999 and an assessment of the significance of the damage in terms of profit loss was therefore only possible for this period.

The economic analysis of bird damage at Katkop includes only quelea and Laughing Doves. Ostriches at Katkop were fed crushed maize in their mixed ration from July 1997 until April 1998, after which it was replaced by whole maize until November 1998. This effectively eliminated feed loss to small granivorous bird species. From December 1998 until ostrich rearing ceased on the farm, no maize was included in the daily ostrich ration.

Table 6.7 shows the percentage of the monthly profits that were lost due to maize consumed by problem birds at Riverside Farm and Katkop. Damage levels varied considerably from less than 1% to almost 50% of the monthly profits, but were generally higher at Riverside Farm. Removal of the maize constituent of the ostrich ration by problem birds varied from 0.1% to as high as 24% in winter at Riverside Farm. This alteration of the composition of the balanced ration could potentially have serious consequences for the growth rate of the ostriches.

Table 6.7 Cost of feed loss to problem birds in relation to monthly production costs and profits from the sale of ostriches for slaughter. The monthly cost, income and profit values are calculated as 1/14th of the total for slaughter age ostriches.

Date (number of ostriches)	Total cost for month	Total income for month	Total profit for month	Value of lost maize for month (% of profit)	% maize removed from mixed ration
Riverside Farm					
January 1999 (400)	R 25 168	R 28 571	R 3 403	R 312 (9.2 %)	4.8 %
February 1999 (400)	R 25 168	R 28 571	R 3 403	R 70 (2.1 %)	1.2 %
March 1999 (500)	R 31 460	R 35 714	R 4 254	R 7 (0.2 %)	0.1 %
April 1999 (700)	R 44 044	R 50 000	R 5 956	R 359 (6.0 %)	3.1 %
May 1999 (300)	R 18 876	R 21 429	R 2 553	R 647 (25.3 %)	13.2 %
June 1999 (550)	R 34 606	R 39 286	R 4 680	R 2 166 (46.3 %)	24.0 %
Katkop					
July 1997 (270)	R 15 510	R 19 286	R 3 776	R 37 (1.0 %)	0.8 %
August 1997 (no data)	-	-	-	-	
September 1997 (180)	R 10 340	R 12 857	R 2 517	R 35 (1.4 %)	1.2 %
October 1997 (170)	R 9 765	R 12 143	R 2 378	R 60 (2.5 %)	2.2 %
November 1997 (140)	R 8 042	R 10 000	R 1 958	R 154 (7.9 %)	6.7 %
December 1997 (no data)	-	-	-	-	
January 1998 (180)	R 10 816	R 12 857	R 2 041	R 104 (5.1 %)	3.5 %
February 1998 (30)	R 1 803	R 2 143	R 340	R 43 (12.6 %)	8.8 %
March 1998 (30)	R 1 803	R 2 143	R 340	R 7 (2.1 %)	1.4 %
April 1998 (30)	R 1803	R 2143	R 340	R 5 (1.5 %)	1.0 %
May 1998 (no)	-	-	-	-	
June 1998 (110)	R 6 115	R 7 857	R 1 742	R 3 (0.2 %)	0.2 %
July 1998 (100)	R 5 559	R 7 143	R 1 584	R 4 (0.3 %)	0.3 %
August 1998 (100)	R 5 559	R 7 143	R 1 584	R 3 (0.2 %)	0.2 %
September 1998 (100)	R 5 559	R 7 143	R 1 584	R 13 (0.8 %)	1.0 %
October 1998 (120)	R 6 671	R 8 571	R 1 900	R 35 (1.8 %)	2.3 %
November 1998 (65)	R 3 613	R 4 643	R 1 030	R 97 (9.4 %)	11.8 %

6.3.8 Estimate of total annual consumption of crushed maize by problem birds in the Eastern Cape.

No information on losses of feed to problem birds at ostrich feedlots in the Eastern Cape was available from either the East Cape Ostrich Producers Association (ECOPA) or any of the agricultural extension officers in the province. But, given that approximately 60 000 ostriches were raised annually in the Eastern Cape between 1997 and 1999 (Chapter 3) with a mean profit of approximately R 9 000 000 per annum, it is possible to make a very rough estimate of losses due to problem birds for the whole province. Assuming an average loss of profits due to maize consumed by problem birds of 7 % (derived from Table 6.7), losses may have amounted to as much as R 600 000 in the province as a whole. Approximately one quarter of all ostrich farmers registered with the ECOPA in the late 1990s were from the Cradock and Somerset East magisterial districts and it is therefore possible that farmers in these areas alone sustained losses of up to R 150 000 over this period.

6.4 DISCUSSION

Agricultural crops, livestock feed and stored cereals are important sources of food for many bird species, especially during periods when their natural food is scarce. The number of birds utilising these artificial sources, and hence the amount of damage caused, is therefore often related to the availability of alternative food sources (Feare & Swannack 1978; Toor *et al.* 1986; Bucher 1990). Quelea appear to have adapted their feeding behaviour to enable them to fully exploit this relatively new and reliable resource and, as with European Starlings in Britain and Europe (Feare 1989), they are most dependent on livestock feed over the lean winter and early spring period. Increased dependence on man-made food sources during winter is a familiar pattern for quelea throughout Africa (Ward 1965; Gichuki 1984; Erickson 1989; Jarvis & Vernon 1989a) and indeed for many other species around the world (Besser *et al.* 1968; Palmer 1972; Feare & Swannack 1978; Folk & Kožená 1982; Glahn *et al.* 1983; Glahn & Otis 1986; Toor *et al.* 1986). But heavy dependence on crushed maize continues through spring for quelea in the Eastern Cape when the first rains cause the remaining grass seed to germinate. And it appears that maize is one of the most important food sources during the potentially energetically expensive processes of complete and pre-nuptial moult.

Since food shortages in the lean season are thought to be one of the most important factors regulating quelea population size (Ward 1965), availability of predictable supplementary food sources could reduce winter mortality (Jarvis & Vernon 1989a) resulting in localised population increases. Small variations in survival rate may have large impacts on population size (Green in press, in Siriwardena *et al.* 1999) and this may explain the increase in the breeding population of quelea in South Africa between the 1930s and 1950s (Naude 1959). Similar patterns have been observed elsewhere for species such as the Eared Dove (Bucher 1990), but these localised increases may equally be attributed to changes in bird movement patterns in response to changing agricultural practices which make food more readily available in certain areas (Gramet & Dubaille 1983; Feare 1994), or to increased sedentariness. These alternatives are not mutually exclusive.

Berruti (1995) was the first to report that quelea rely on artificial food sources such as crushed maize well beyond the traditional lean period. This behaviour is not unique to quelea and in some areas rice may be the dominant food for blackbirds (Icteridae) throughout the non-breeding period (Rodriguez & Avery 1996). Even though maize and other grains used in livestock feed have slightly lower energy value than natural seeds (Wiens & Dyer 1975), the reduced foraging time expended by birds exploiting this resource appears to be beneficial (Feare 1984). It also suggests that suitable natural food resources are limited in the Eastern Cape, and that they are insufficient to support the artificially large numbers of quelea in this traditionally marginal area of their range.

Quelea apparently foraging at the same sites showed considerable variation in diet even within monthly samples. Variation was, however, minimal in spring when dependence on maize was highest. Ward (1965) found similar variation among birds collected at roosts, but suggested that individual birds may change the composition of their diet frequently, and thus over time their diet will resemble the average for the whole community. In contrast, Feare (1984) found that the same dominant section of starling population tended to return to the calf feedlots each day. Even so they did make use of the grass fields where the rest of the flock was feeding (Feare 1984), which suggests that some component of the diet was lacking in the livestock feed. The importance of a mixed diet of invertebrates and cereals has subsequently been demonstrated (Feare & McGinnity 1986, in Feare 1989). Similarly, while quelea are not dependent on insects outside of the breeding season, and have been successfully kept in captivity on a diet of millet (Lourens 1963), caged quelea fed only crushed maize lost weight and began to die after several weeks (pers. obs.). Some nutrients that may be obtained from natural grasses are clearly essential. Similar loss of condition by birds on restricted diets has been reported for Chaffinches *Fringilla coelebs* (Kear 1962, in Brown 1969) and Partridge *Perdix perdix* (Pulliainen 1965, in Brown 1969).

Although little is known about the ability of quelea to assimilate various foods (Ward 1965), the lower energy value of maize (17.8 KJ/g dry wt) (Wiens & Dyer 1975) relative to dehusked grass seeds (18.4 KJ/g dry wt) (Ward 1965), may explain why cage birds fed on crushed maize consumed slightly more food on average (2.99 g) than the 2-2.5 g predicted for similar temperatures by Ward (1965). Winter estimates in this study varied from 4.45 g to 4.60 g per bird depending on whether individuals or groups of birds were being tested. The latter estimate is identical to that obtained for birds fed dehusked rice at the same time of year (Elliott 1979). Differences between summer and winter consumption values may be attributed to the greatly increased thermoregulatory requirements of these birds at low temperatures (Tinney 1997) and to the additional costs of complete moult that takes place at this time. Tinney (1997) did not measure the daily energy costs of free-living quelea, but by using the allometric equation of Nagy (1987) ($0.398W^{0.85}$) it is possible to infer daily consumption values for free-living birds. A free-living quelea of 18g would be expected to eat 4.6 g per day in summer, approximately 53% more than was measured for caged individuals. Daily consumption estimates should therefore be considered as conservative.

The graph of estimated damage at Katkop (Figure 6.6) gives the misleading impression that quelea are most dependent on maize in spring and summer. Examination of gut contents, however, revealed that highest proportions of maize were consumed in winter and spring as expected. The reason for this apparent anomaly is the relatively greater contribution of Laughing Doves to the overall damage estimate at this site than at Riverside Farm and the greater number of supplementary feeding sites available to quelea in the Katkop area. Subsequent observations at other sources of crushed maize in this area (Katkop cattle feedlot, Katkop dairy and the Lowlands Estate cattle and ostrich feedlots) demonstrate a high dependence on artificial food sources throughout the year. Approximately 2000 quelea fed at the Katkop cattle feedlot in May and June 1998 and over 4000 quelea fed at the dairy throughout autumn and winter 1999. During winter 1999 natural seeds were considerably more important in the diet of quelea at Katkop than over the same period in previous years, possibly as a result of the higher than average rainfall in December 1998 in the Cradock area. Ward (1965) attributed similar reductions in crop damage to a plentiful supply of grass seeds following good rains. Such observations emphasise the need for continued assessment of bird damage since apparent "patterns" may well change dramatically even between successive years.

Inadequate samples and a large unidentified component made it difficult to establish seasonal feeding preferences of Laughing Doves at Katkop from gut content analysis. They appeared to prefer feeding in maize stubble and only returned to the feedlot in large numbers when these fields were ploughed. This may explain the relatively high levels of maize in their diet in winter and early spring 1998 when numbers of birds, and hence damage at the feedlot, was estimated to be lowest. Similarly, Little (1994) found that Rock Pigeons preferred to feed in wheat fields away from human disturbance, and nearby dairy feedlots were utilised only by Feral Pigeons *Columba livia*. At Riverside Farm, Rock Pigeons utilised both fields and feedlot, and crushed maize was the main component of their diet in all samples.

The influx of Laughing Doves at the Riverside Farm ostrich feedlot during the summer breeding season conforms to their observed movement patterns in other areas of southern Africa (Colahan & Harrison 1997). The summer influx of Rock Pigeons was, however, contrary to the expected movement patterns for this species in the Eastern Cape (Colahan 1997). Though capable of breeding throughout the year, records suggest that both Rock Pigeons and Laughing Doves show a spring to early summer reproductive peak in the Eastern Cape (Rowan 1983; Colahan 1997; Colahan & Harrison 1997). Commercial grain crops are considered crucial to the stability and breeding success of Laughing Dove populations elsewhere in South Africa (Dean 1979), and birds in this region may similarly be heavily dependent on the abundant availability of crushed maize at feedlots.

Doves are relatively independent of animal food during the breeding season because of their capacity to produce crop milk to feed to nestlings (Bucher 1990). Nevertheless, termites, fly larvae and pupae and small snails, which form the main animal component of their diet, are considered important during egg formation (Dean 1979). Quelea, in contrast, are dependent on large numbers of soft-bodied insects such as caterpillars, termites and grasshopper nymphs for feeding their chicks (Lourens 1963; Jones 1989d). The relatively high proportion of insects in the diet of quelea at Riverside Farm during spring 1997 (4.8%) occurred at a time when birds were undergoing pre-nuptial moult. This contradicts earlier findings that adult quelea did not appear to increase personal consumption of insects over the breeding season (Lourens 1963), but is supported by Gichuki (1984) who found that consumption of animal matter increased as quelea moulted and prepared to breed. His estimates of 3.7-7.6% animal matter are comparable to the 4.8-9.4% estimated for the same period in this study.

Increased insect consumption (particularly of termite alates) is also characteristic of pre-migratory fattening in preparation for early-rains migration (Ward & Jones 1977;

Manyanza 1980) and it is possible that a small proportion of quelea at Riverside Farm were building reserves in order to undertake such a movement. The majority of quelea, however, remained at the feedlot until mid summer (Appendix 5) by which time pre-nuptial moult was complete and food was likely to be available throughout much of their range making accumulation of large fat deposits unecessary. Whether termites were consumed specifically for fattening, to suppliment the energetic demands of pre-nuptial moult or simply because they were available is not known, but many species including Wattled and Pied Starlings and even Lanner Falcons *Falco biarmicus* gorge themselves opportunistically on termite alates when they are swarming (Rowan 1969; pers. obs.).

Subsequent high levels of termites and winged ants in the diet of those quelea that remained at Riverside Farm during summer and autumn 1998 correspond closely to the 8.3% insects in the diet of quelea feeding 10-20 day old nestlings (Lourens 1963) and may well indicate that chicks were being reared. At Katkop, winged ants comprised 95% by weight of insects consumed during summer 1998-1999. The peak of 8.7% insects in the diet of adults over this period is again similar to that recorded for quelea feeding nestlings and may indicate breeding. Small numbers of insects were eaten throughout the year at both sites, which is normal behaviour for quelea. These were predominantly small Curculionid beetles that, though unsuitable for feeding chicks (Lourens 1963), may well serve as a source of vital amino acids (Ward 1965).

While both quelea and Laughing Doves ate a wide variety of seeds over the study period most of these were eaten by only a few individuals, thus leaving relatively few species that appeared to be important. Indeed, Ward (1965) found that as few as one to three food items typically comprised the bulk of food of birds sampled at one roost. This implied capacity to diversify their diet is crucial to the survival of many species during times of food shortage (Rowan 1969).

Seeds of *Amaranthus* and *Chenopodium* spp. and *Echinochloa* spp. were among the main non-maize, vegetable component of the diet of Laughing Doves and quelea at all three feedlots, either in terms of the number of individuals that ate them, or their percentage of the total dry organic mass, or both. *Urochloa panicoides* was similarly important to all but the Laughing Doves at Brandeston, while *Panicum* sp. was important in the diet of quelea at Riverside Farm and Laughing Doves and quelea at

Katkop/Lowlands Estate. This apparent preference for the same species is surprising, since to avoid competition different bird species with overlapping distributions would be expected to take different foods. However, when food supplies are plentiful, sharing may occur and even dietary overlap exceeding 50% between House Sparrows and Collared Turtle Doves *Streptopelia decaocto* sampled on farms in Czechoslovakia was not considered significant (Folk & Kožená 1982).

Since the actual abundance of seeds of the various grass and weed species available to birds at the feedlots was not quantified, it was not possible to determine whether these species were indeed preferred foods or merely a reflection of the relative abundance/availability of the different food sources. Therefore, while this apparent "preference" for the same species of seed may simply be a reflection of limited local availability of different seeds (Brown 1969), *Amaranthus* sp. and *Urochloa* sp. have been previously recorded in the diet of both quelea and Laughing Doves (Lourens 1963; Dean 1979; Gichuki 1984; Erickson 1989). Indeed, the annual grasses *Urochloa*, *Echinochloa* and *Panicum* spp. are classified as small (Ward 1965; Erickson 1989) and thus appear to be among the most preferred foods of quelea throughout Africa (Lourens 1963; Ward 1965; GTZ 1987; Erickson 1989; Jarvis & Vernon 1989a; Soobramoney 1998). *Amaranthus* and *Chenopodium* spp. are considerably smaller and fall into the minute category (Ward 1965; Erickson 1989).

Laughing Doves apparently show a strong preference for small black seeds (Dean 1979; Gichuki 1984) and at times these may be consumed in bulk (Gichuki 1984). *Amaranthus* and *Chenopodium* spp. are also important components of the diet of the Eared Dove in Argentina (Murton *et al.* 1974), which has a very similar ecology to that of the Laughing Dove (Rowan 1983). *Chenopodium* sp. is also eaten by Stock Doves *Columba oenas* and Turtle Doves *Streptopelia turtur* in Britain (Murton *et al.* 1964a). Seeds of species of *Atriplex, Rhus* and *Solanum,* commonly found in the diet of Laughing Doves at Riverside Farm and Katkop, have also been previously recorded for this species (Dean 1979; Rowan 1983). Though not listed as eaten by Laughing Doves (Dean 1979; Rowan 1983), *Echinochloa* spp. were important grasses in the diet of the Eared Dove (Murton *et al.* 1974).

Amaranthus and *Chenopodium* spp. were eaten throughout the year by Laughing Doves at both Riverside Farm and Katkop, but mainly in winter and spring by quelea when it is expected that their preferred seeds would be in short supply. Nevertheless, over this period such seeds may well provide a valuable source of nutrients not available from maize. Minute and large seeds become increasingly important in the diet of quelea as the dry season progresses and stocks of preferred small seeds become depleted (Ward 1965; Ward 1973a; GTZ 1987; Erickson 1989). Maize eaten by quelea ranged from minute to very large (pers. obs.), but given the choice pieces 1-2 mm in size were preferred (Chapter 7). Following the spring rains the remaining seeds germinated and small seeds dominated the non-maize, vegetable component of the diet again in summer and autumn.

Although Wattled Starlings have been recorded taking maize meal from seed trays (Dean 1989) and Pied Starlings are known to feed on maize crops (Kok & van Ee 1990), the high proportion of crushed maize in their annual diet at Riverside Farm and Katkop was still unexpected. In this instance such atypical feeding behaviour may be attributed to opportunistic exploitation of an unusually abundant food source, but is also characteristic of birds faced with acute food shortages (Rowan 1969). Wattled Starlings typically eat insects, snails, fruit and nectar (Kok & van Ee 1990) while Pied Starlings have a more varied diet and will also eat seeds, centipedes and small lizards (Craig 1989b; Feare & Craig 1998).

Removal of maize from the ostrich ration by birds is a constant problem, but damage is generally greatest in winter and spring when quelea and starlings are most abundant and lowest in summer when doves and pigeons are the main problem. It is therefore vital that management decisions should consider seasonal shifts in the composition of the problem bird population and changes in the extent of damage, if control options are to be successfully implemented and remain cost effective.

The proportion of monthly profits that can acceptably be lost to problem birds is likely to vary from one farm to the next depending on a variety of factors. These may include, among other things, the overall financial situation of the owner and the personal conservation beliefs of the manager. Low levels of damage may be tolerated for extended periods without compromising the long-term profitability of the farming operation, but Dolbeer (1986) suggests that damage exceeding 5% of production may be considered significant. However, it may be argued that losses become significant when they exceed the costs of implementing an appropriate strategy to prevent or contain the damage. For example, maize loss must exceed 4 % of the monthly profits if the increased cost of adding orange pulp to the ostrich ration as a feeding repellent (approximately 2c per ostrich per day in 1999) is to be economically viable (Chapter 7). In such a case, damage exceeding 4% of the monthly profits would be considered significant.

At Katkop, the number of ostriches kept at any one time was usually low and given the large variety of alternative sources of food (e.g. field crops, cattle feedlot, dairy and cattle and ostrich feedlots on Lowlands Estate) the feed losses at the Katkop ostrich feedlot only exceeded 4% in four out of the fourteen months for which data was available. The only economically viable option for reducing damage in most months would therefore have been to replace the crushed maize with cheaper whole maize (Chapter 7), unfortunately this is no deterrent to larger birds such as doves. Feed losses at the Katkop dairy were not calculated, but given that several thousand quelea fed there on a regular basis, losses are likely to have warranted some form of damage reduction.

Bird damage at feedlots can be divided into that which can be directly measured and that which requires additional research and cannot, as yet, be quantified. Food intended for ostriches that is eaten by problem birds has a direct quantifiable cost to the farmer (more than R 2 000 at Riverside Farm in June 1999). But, in addition to the obvious direct market implications, maize eaten by problem birds during periods of heavy damage may represent a significant proportion of the high-energy component of the livestock ration. Indeed, problem birds were estimated to have removed 24% of the maize constituent of the mixed ration provided to ostriches at the Riverside Farm feedlot in June 1999. This greatly exceeds the proportion of barley (15%) consumed by European Starlings at one cattle feedlot in Britain (Feare & Wadsworth 1981).

By altering the composition of the ration, problem birds can potentially have a serious negative impact on the growth rate of livestock (Feare & Swannack 1978), the financial implications of which have yet to be investigated for ostriches. In Britain, calves fed in protected enclosures grew faster than those exposed to competition with European Starlings, resulting in an increased profit of £ 3 per animal in the 1970s (Feare 1980). The full financial benefits of taking steps to reduce maize loss to problem birds at ostrich feedlots are therefore likely to exceed the value of the maize itself.

Other potential bird problems at feedlots that require additional research include claims that bird faeces may reduce the palatability of the feed and claims that birds at feedlots are responsible for transmitting diseases to livestock (Feare & Swannack 1978; Feare 1980; Feare & Wadsworth 1981). Since ostriches may be given poultry manure as a feed supplement (M. Biggs pers. comm.), it is unlikely that contamination of food by bird droppings would render the ostrich ration unpalatable. Indeed, in sufficient quantities bird droppings may even improve the growth performance of ostriches.

Birds are highly mobile vectors of disease and while they are unlikely to pose a serious threat of infection to cattle (Feare 1989), they could potentially transmit viruses to ostriches. Risks of Newcastle Disease being transmitted by quelea are considered minimal (Vickers & Hanson 1979), but quelea do carry ticks (pers. obs.) and could therefore potentially spread tick-borne diseases. Existing quarantine pens are not bird proof and since the cost of enclosing these facilities is likely to be prohibitive, other methods of reducing bird visits should be sought.

6.5 CONCLUSIONS

Most bird species sampled at the feedlots consumed maize to some extent, but quelea, Laughing Doves, Rock Pigeons and Wattled Starlings were responsible for most of the damage. Dependence on this artificial food source varied seasonally and between species, and feed loss only reached economically significant levels in some months. A wide variety of grass and weed seeds were also utilised by birds captured at the feedlots and large-scale immigration and emigration may be triggered by seasonal changes in the availability of these alternative food sources.

7 CHAPTER SEVEN

REDUCTION OF LOSSES CAUSED BY GRANIVOROUS BIRDS AT OSTRICH FEEDLOTS

7.1 INTRODUCTION

Bird damage at intensive livestock feeding operations is not a new phenomenon and much effort has been expended in trying to solve this problem for a wide range of species including the Little Corella *Cacatua pastinator* (Massam 1990), the European Starling (Long 1965; Royall *et al.* 1967; Palmer 1972; Feare & Swannack 1978; Feare & Wadsworth 1981; Feare *et al.* 1981; Glahn & Otis 1986; Glahn *et al.* 1989; Johnson & Glahn 1994), the Brown-headed Cowbird *Molothrus ater* (Glahn & Otis 1986), the Indian Myna *Acridotheres tristis* (Long 1968), the Feral Pigeon (Little 1994; Williams & Corrigan 1994), the House Sparrow (Fitzwater 1994) and the Rook *Corvus frugilegus* (Feare 1974). Depending on the individual situation, species involved and economic cost of the damage, various lethal and non-lethal control options are available.

The most obvious approach to reducing bird damage would be to remove or reduce access to feed. This can be done in a number of ways. Enclosing the feeding areas with some form of exclusion netting has proved very effective against quelea at pig rearing facilities (M. Schulpfort, pers. comm.) and against sparrows and weavers at poultry farms (pers. obs.) in the Eastern Cape Province of South Africa, as well as against European Starlings at calf yards in Britain (Feare & Swannack 1978). This can be a very expensive approach and unless, as in the examples mentioned, existing buildings are merely being bird-proofed, it is generally only considered economically viable when protecting relatively small areas of high value crops such as grapes & cherries (Plesser *et al.* 1983; Feare 1984; Feare *et al.* 1986; Long 1990; Fieldler *et al.* 1991; Fitzwater 1994; Porter & McLennan 1995; Dolbeer 1997). Although exclusion netting may appear harmless, mortality of non-target birds through entanglement in netting may be high (Twedt 1980; Feare *et al.* 1986).

An alternative approach is to limit the period during which food is available to livestock and hence exposed to problem bird species. By timing feeding to coincide with the periods when lowest bird numbers are expected (i.e. early morning before birds arrive and late afternoon after most have departed to the night roost) feed loss can be minimised (Feare *et al.*1986; Johnson & Glahn 1994). However, in an attempt to maximise growth rates many managers ensure that ostriches have continuous access to food, in some cases replenishing food twice a day (Plate 11). Consequently, problem birds can obtain their daily food requirements at leisure.

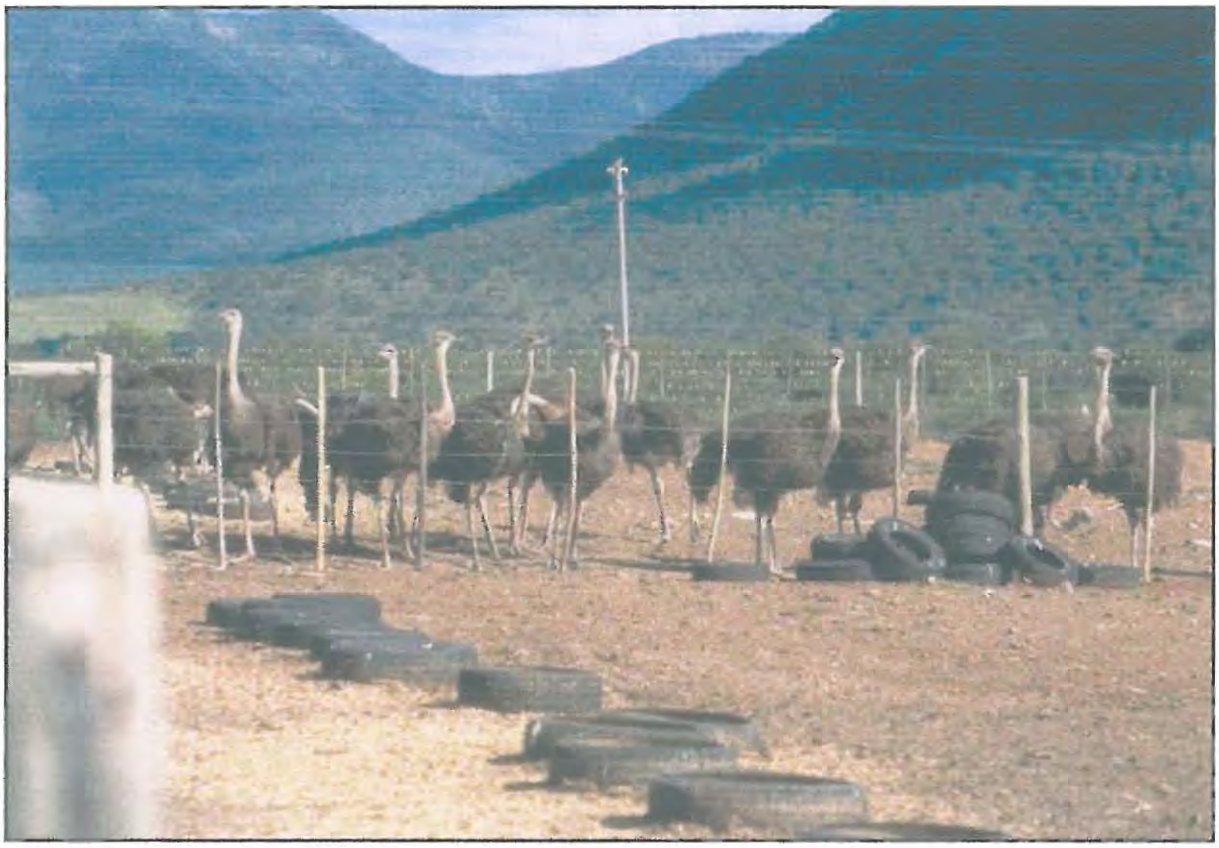


Plate 11 Ostrich feedlot at Riverside Farm where husbandry techniques ensure that ostriches and problem birds have a continuous supply of food.

The use of bird-proof livestock feeders such as flip-top pig feeders (Johnson & Glahn 1994) and modifying feed presentation thus appear to be the most appropriate and economical approaches to limiting exploitation of ostrich feed by other birds. Through our knowledge of the feeding preferences of problem birds, it is possible to alter the way in which the livestock feed is presented to reduce its attractiveness to these species.

From studies of their diet, Ward (1973a) deduced that quelea prefer seeds of 1-2 mm in diameter, although both larger and smaller seeds will be taken when preferred sizes are in short supply. Most crushed maize used in commercial cattle and ostrich feed in the Eastern Cape is < 3 mm in size (pers. obs.) and thus ideal for exploitation by quelea. Maize comprises a large proportion of the diet of granivorous birds at ostrich feedlots and in months when their populations are large, losses may become economically significant and steps need to be taken to reduce their impact (Chapter 6). Control techniques must, however, remain cost-effective. The aims of this study were to test Ward's field observations of quelea seed size preferences under more controlled laboratory conditions, and to determine if altering the size of crushed maize in ostrich feed could be used to eliminate this as a suitable food source for quelea.

Considerable effort has been expended in developing bird proof varieties of crops (Bucher & Bedano 1976; Bullard & Gebrekidan 1989; Crocker & Perry 1990; Dolbeer 1990; Tarimo 1999). Repellent varieties may be protected by chemical compounds that are unpalatable to birds or that make them ill (Crocker & Perry 1990). These are only effective when alternative food is available (Bruggers *et al.* 1998). An alternative to genetically engineered varieties is to spray the plants with repellent compounds (Rodriguez *et al.* 1997). Methyl anthranilate is a human and livestock food flavouring that may act as a feeding deterrent to birds (Mason & Clark 1995). While its success in protecting crops has been variable (Avery 1995; Mason & Clark 1995), when mixed with cattle feed it provides a cost-effective repellent against European Starlings at feedlots (Johnson & Glahn 1994). Natural plant products such as extracts of neem and garlic have also shown promising repellent properties in laboratory choice tests (Mason & Matthew 1996; Mason & Linz 1997). Similarly, anecdotal information suggests the addition of orange pulp (20% by weight of feed), a relatively cheap waste product of the local juice industry, as a supplement in dairy feed (maize, meal & lucerne) may have a repellent effect on House Sparrows and Laughing Doves (G. Gush, pers. comm.). A series of experiments were therefore conducted to determine the effectiveness of orange pulp as a quelea feeding repellent.

Various visual and auditory scarers are widely used to repel birds from crops and grain storage facilities, but with mixed results (Long 1962; Tyler 1979; Jarvis 1983; Conover 1984; Fazlul Haque & Broom 1985; Fiedler *et al.* 1991; Conover & Dolbeer 1989; Long *et al.* 1989; Long 1990; Bergman *et al.* 1997; Dolbeer 1997). The effectiveness of scarers depends on the availability of alternative food sources and on the diligence of operators. Unless frequently adjusted and varied, birds soon become habituated to the disturbances and are no longer frightened away (Boudreau 1968; Feare 1974; Feare *et al.* 1986; Aubin 1990; Bomford & O'Brien 1990; Milsom 1990; Linz *et al.* 1993b; Yokoyama & Nakamura 1993; Dolbeer *et al.* 1994; Avery & Matteson 1995; McLennan *et al.* 1995; Nakamura *et al.* 1995; Dolbeer 1997). In areas of large-scale cereal production, scarers merely concentrate birds in unprotected fields and do not reduce overall losses (Ward 1979). Once birds become established in an area in large numbers it is usually very difficult to discourage them from feeding, so damage prevention should be initiated while pest numbers are still relatively low (Avery 1995; Rodriguez *et al.* 1997). This unfortunately increases the risk of habituation. Given the expense of many of these systems and the need for regular monitoring and adjustment, it is unlikely that they present a viable control option at ostrich feedlots, especially since the greatest impact of problem birds is in winter when alternative natural food sources are in short supply.

In some situations lethal control is the most appropriate or only effective means of limiting damage. Where no alternative food sources are available, neither scarers nor repellent chemicals are likely to deter feeding. The aim remains, however, to limit the impact of control on non-target species. Killing of problem quelea with explosives or aerially applied poisons are well established and widely accepted control methods. In recent years awareness of, and concern for, the detrimental environmental consequences of such control operations has increased. Aerial application of the avicide Fenthion (an organophosphate pesticide) affects a wide range of species including birds, mammals and insects and non-target mortality may be high (Becker & Amir 1993; Keith *et al.* 1994, Keith & Bruggers 1998). Off-target drift (up to 3 km), highly toxic and persistent residues and poor knockdown of target birds greatly increase the risks of secondary poisoning (Van der Walt 1998). Improvement of existing control measures and development of alternative ones were identified as research priorities at the 1999 "Migrant pests of agriculture in southern Africa" workshop in Pretoria.

The theoretical advantage of using a narcotic rather than a fast acting poison is that non-target species taking the bait can be revived (Ridpath *et al.* 1961). Problem birds may be killed or translocated as the situation requires. It is not, however, possible to prevent overdosing and some non-target mortality is inevitable when baiting occurs in rural areas (Thearle 1969). The narcotic alpha-chloralose does not appear to cause stress and is considered to be a humane method of control (Borg 1955; Woronecki *et al.* 1992). It has been in used to control problem birds since 1942 (Daude 1942, in Brunet *et al.* 1996) and has subsequently been registered as an avian control agent in Great Britain, France, New Zealand and Australia (Woronecki *et al.* 1990). In 1992 approval was given for its restricted use in the United States (Woronecki & Dolbeer 1994).

Basic toxicity parameters of alpha-chloralose such as LD_{50} have been calculated for quelea (Allan 1996), but much higher dosages than used in force-feeding experiments may be required to achieve results in the field because bait intake cannot be controlled as easily (Stouffer & Caccamise 1991). The aim of this work was therefore to determine the most effective concentration (MEC) of alpha-chloralose for use against quelea in control operations at ostrich feedlots, and the effect of this concentration on various other species utilising the feedlots. MEC is defined as the minimum dosage required to achieve, with relatively low mortality, the rapid capture of a large proportion of baited birds.

7.2 MATERIALS & METHODS

7.2.1 Capture and maintenance of experimental birds.

Spotted-backed Weavers for use in alpha-chloralose experiments were captured on the farm Resolution Hatchery near Fort Brown. Information on the capture of other bird species used in the following experiments, and additional details on their treatment prior to experiments are provided in section 6.2.3 of Chapter 6.

7.2.2 Determination of quelea food size preferences.

Descending preference experiments were conducted with groups of five quelea in the smaller indoor cages following a one week acclimation period during which crushed maize and water were provided *ad libitum*. Five size categories of crushed maize were used in experiments and were selected according to available sieves: >4.8 mm (including some whole maize), <4.8>3 mm, <3>2 mm, <2>1 mm, and <1 mm. Thirty grams of maize of each size category was presented in separate polystyrene containers attached to a strip of cardboard to prevent them from being tipped over. The arrangement of the containers varied randomly between replicates (n=13). Food was removed overnight and the experimental feed introduced before 09h00 the following morning. Spilt maize was collected in a tray placed below each cage and was re-sieved and returned to the correct container when food was removed at dusk, and then reweighed. The mass of maize eaten from each category was calculated. Consumption of the different categories was compared by means of a One-way Analysis-of-Variance (ANOVA) to determine preference.

Once the preferred size category of maize had been established it was removed and the choice experiments were repeated with six of the original 13 groups. This process of elimination continued with subsequent "preferred" size categories until an unsuitable seed size was identified. Mean daily consumption per bird was used as a measure of whether food was becoming unsuitable. A two-day rest period, during which birds were fed mixed birdseed, was allowed between consecutive elimination experiments.

Reducing the number of food bowls during the course of the experiments should not have affected daily consumption since each bowl contained sufficient food for all five birds. Fewer containers with suitable food would create greater competition at feeding time, but since quelea need to feed for only a short time each day to obtain their daily requirement of food (Ward 1979), all birds should have had adequate access to the food.

The largest size category (>4.8 mm), which included whole seeds, was minimally exploited throughout the preference trials. Since six quelea accidentally deprived of food for 24 hours during an earlier experiment died, it was decided to measure food consumption of the least preferred category only during the morning (09h00-13h00). This allowed birds sufficient time to feed before nightfall.

7.2.3 Field tests of whole maize as a deterrent for small granivorous birds.

It was not possible to design specific field tests using whole maize because of the presumed (by farmers and managers) negative effect of feeding whole maize on ostrich growth rates. An opportunity for indirectly testing the deterrent value of whole maize arose as a result of a decline in the ostrich market. To save time and costs, whole maize replaced crushed maize in the ostrich ration at Katkop. Numbers of granivorous birds at the feedlots and in the surrounding areas had been routinely monitored for several months prior to this change in the feed ration and therefore provided a useful comparison (Chapter 4).

7.2.4 Repellency of orange pulp in commercial ostrich feed to quelea.

Preliminary experiments were conducted to test whether orange pulp in commercial ostrich feed was repellent to quelea in the absence of an alternative food source. Seven groups of quelea (five birds per group) were placed in smaller outdoor cages to acclimate. Mixed birdseed was provided to all groups for the first three days after which feed type varied among groups.

Three control groups were used. Quelea in the first control were fed mixed birdseed throughout the acclimation and experimental periods to determine normal daily fluctuations in individual body mass. Birds in the remaining two groups were fed crushed maize and untreated ostrich feed (21% maize, 32% lucerne and 47% fish meal) respectively, from day four onwards, as controls for the effects of diet change and increased foraging difficulty. Birds in the remaining four groups were fed untreated ostrich feed on the final two days of acclimation (days four and five), and then 250g of an ostrich feed mix comprising 60% orange pulp on the day of the experiment.

Unpalatable food preparations were expected to reduce feeding, resulting in weight loss by experimental birds. Mass of each bird was therefore recorded at dusk from the third day of acclimation until the end of the experiment as a measure of the effect of the various treatments on their daily consumption.

7.2.5 Repellency of crushed maize treated with orange to quelea.

A sequence of paired-choice experiments was conducted with eight quelea to assess the repellent value of orange in the presence of an alternative food source. Four treatments, 20% orange juice and three concentrations of grated orange rind (20%, 10% and 5%) by weight of maize, were compared. In a final experiment, maize treated with 20% grated rind was presented in a no-choice test to evaluate the effectiveness of this technique in the absence of alternative food sources. The grated orange rind was thoroughly mixed in with the crushed maize so that the "acidic juices" from the rind coated the maize surface.

Quelea were placed individually into smaller outdoor cages for a five day acclimation period. Untreated crushed maize was provided in two identical containers for the last two days of acclimation. Consumption from each container was recorded on the final day of acclimation as a measure of normal daily intake, and to confirm that birds fed randomly from both containers. The same birds were used throughout the experimental series to allow a direct comparison of the relative palatability of untreated and treated feed between treatments (Mason & Linz 1997). Five containers of treated maize placed in an unused outdoor cage served as controls for evaporative water loss (EWL) in each experiment.

Feed was removed overnight before each experiment. The next morning 20 g of treated and untreated feed were presented to birds in identical containers before 08h30 and removed again at dusk. Consumption of treated (corrected for EWL) and untreated maize was measured by weighing remaining feed. Differences in consumption were tested for significance using a One-way ANOVA.

7.2.6 Determination of the most effective concentration of alpha-chloralose.

Preparation of alpha-chloralose bait.

To improve the adherence of alpha-chloralose, crushed maize (>1<3 mm) was sieved and washed in tap water to remove fine dust and then allowed to dry at room temperature. Five concentrations of alpha-chloralose (supplied by Horticura, Pretoria) were tested: 0.5%, 1%, 1.5%, 2% and 2.5% by weight in food. Alpha-chloralose powder was added to the cleaned maize and thoroughly mixed by vigorous shaking in a sealed plastic container for at least 1 min. 1 ml of sunflower cooking oil was added per 50 g of maize as a sticker and the contents shaken for a further minute. The maize bait was then allowed to "dry" overnight at room temperature. One of the advantages of this preparation method is that the maize need not be digested for the alpha-chloralose to be absorbed (Murton *et al.* 1963).

All experimental birds were individually caged outdoors and fed mixed birdseed for the first two days of acclimation and then crushed maize for the remaining period. In order to reduce the influence of variability among test animals on the perceived effectiveness of the various alpha-chloralose concentrations, sets of birds similar with respect to sex, age (adult or juvenile), mass and moult state (presence/absence of wing moult) were used in the different replicates. In each replicate one control bird was maintained on a diet of mixed birdseed throughout, while a second was given the same treatment as experimental birds but fed crushed maize treated with only the sunflower oil sticker on the day of the experiment. Each of the five experimental birds in each replicate received a different concentration of alpha-chloralose and simultaneous testing of the various treatments controlled for differences in ambient temperature amongst replicates. Ten replicates were conducted for each treatment except 2.5% alpha-chloralose, for which there were only nine.

The day prior to the experiment, all food was removed at dusk and birds were weighed using a 60 g capacity Pesola balance (accurate to 0.5 g) to determine the effects of the acclimation period and diet change on bird condition. Birds were deprived of food overnight to simulate conditions in the field. Gravel and water were provided *ad libitum*.

Twenty grams of alpha-chloralose bait was placed in the cages at approximately 08h00 the next morning and birds were observed continuously from a hide for the duration of the experiment. Time from the start of feeding to immobilisation, and the behaviour of the treated birds as they became immobilised was recorded. Birds were considered immobilised when they could easily be picked up or caught by hand (Stages 2 to 4 of Ridpath *et al.* 1961). Partially immobilised birds corresponded to stage 1 of Ridpath *et al.* (1961) and required a net for capture, while unaffected birds showed no signs of narcosis.

Immobilised birds were collected and placed individually in cloth bags in a warm, dark room where they were monitored until they recovered and were released back into the outdoor aviary. Birds that did not eat any bait were excluded.

7.2.7 Effect of delayed treatment on bird survival.

Under field conditions it might not always be possible to retrieve affected birds immediately they become immobilised. The effect of delayed treatment on bird survival was therefore tested. Quelea were used as the test species since they were one of the smallest birds likely to eat treated bait and therefore likely to be among the most affected by prolonged exposure. The same procedure was followed as in previous experiments, but in addition to birds collected immediately they became immobilised, some were left for 30 and 60 minutes respectively before being treated. The proportion of quelea that recovered after delayed treatment was compared to those picked up immediately, using a chi-squared test. To control for climatic variability replicates of all three treatments were carried out on the same days. The temperature difference between the start of feeding and the end of the experiment was less than 5°C on all days.

7.2.8 Effect of alpha-chloralose on other species at the feedlot.

To determine the effect of alpha-chloralose baiting on other species likely to consume treated bait, a series of trials was conducted using 1.5% alpha-chloralose in crushed maize. This concentration was determined to be the most effective for use against quelea. Test species included Cape Sparrows, Rock Pigeons, Laughing Doves, Red Bishops, Wattled Starlings, Spotted-backed Weavers and Masked Weavers. Although no Pied Starlings could be caught for laboratory trials, information obtained during field trials suggested that these birds, though highly susceptible to the drug, showed good recovery.

Two days prior to alpha-chloralose treatment all species were switched from their maintenance diet to crushed maize. The remaining procedure was as for quelea.

7.2.9 Field trials with alpha-chloralose.

During the pre-baiting and post-baiting periods morning counts were made of all granivorous species to provide a measure of the effect of alpha-chloralose baiting on bird numbers at the feedlots. In May only three groups of ostrich pens were still occupied, thereby concentrating the remaining flocks of foraging quelea. A site comprising five pens in the middle of the feedlot, within 20 m of a popular secondary (day) roost, was selected for baiting. Initially three of the pens contained ostriches being fed crushed maize and lucerne, while the remaining two had been unoccupied for several months and were largely covered by weed growth, except for a 5 m wide strip along one fence. Most of the surrounding pens had only recently been emptied and were still largely bare of vegetation, which simplified recovery of stupefied birds.

Attempts to attract birds to the unoccupied camps in the experimental area by pre-baiting with 4 kg of untreated crushed maize for three days were unsuccessful. However, when ostriches were removed from two of the occupied camps in the centre of the experimental area, their uneaten food continued to attract large numbers of foraging birds. This provided a suitable, safe baiting site and experiments with treated bait were initiated.

Approximately 1 kg of treated bait (1.5% alpha-chloralose by weight of crushed maize) was laid down in a strip (2 m by 5 cm) in the centre of the road between the previously occupied pens before the arrival of the first birds. The site was then observed from a vehicle parked approximately 50 m away and movements of feeding flocks monitored to assist in locating stupefied birds. Searches for stupefied birds were begun within 30 min of the first birds showing signs of narcosis. All remaining treated bait was removed at 10h00. The bait site, roosting trees, fence line, all surrounding pens (±100 m radius) and all known roosts sites and feeding points were checked several times during the morning and afternoon.

The following day approximately 1.5 kg of treated bait (1.5% alpha chloralose by weight of maize) was again laid down in the road but in a longer strip (4 m x 5 cm) where feeding had been concentrated the previous day. An additional 1 kg of bait was placed in an old tyre (similar to those used as feed containers) in one of the recently vacated pens. The site was again observed from a parked vehicle. All bait was removed by 08h20, and the surrounding area searched as before. The effectiveness of baiting was assessed as the proportion of birds counted feeding at the bait that were later found stupefied.

Research into the use of alpha-chloralose for the control of problem birds at livestock feedlots was approved by the Registrar Livestock Improvement, National Department of Agriculture, Pretoria.

7.3 RESULTS

7.3.1 Manipulation of complete ration constituents.

Descending preference experiments.

During the first choice experiments (Table 7.1) birds showed a significant preference (P<0.001) for crushed maize <2>1 mm in size, selectively eating more of this in nine out of 13 replicates. It was therefore the first category to be eliminated. The size category preferred in the remaining four replicates (<3 >2 mm) then became the preferred size in the second set of experiments. Mean daily consumption per bird dropped 26% from 3.5 g (n=13) in the first experiments to 2.6 g (n=6) in the second. On removal of seeds <3 >2 mm, average daily consumption surprisingly rose to 3.3 g per bird per day with birds showing a significant preference (P <0.001) for the size category <4.8>3 mm. In the fourth experiment only the largest and smallest categories remained and while daily consumption dropped to 2.8 g per bird, this still represents 13.7% of body weight, well within the range recorded for wild birds (Jarvis & Vernon 1989a). Consumption of maize >4.8 mm was below 1.0 g per group in all size preference experiments, including the final one where only this size category was provided.

Table 7.1 Mean consumption of various size categories of maize by quelea in multiple cup descending preference experiments. Sample sizes are given in parentheses.

Maize size (mm)	Mean consumption (g) per group (5 birds) ± Standard deviation				
	Exp. 1 (13)	Exp. 2 (6)	Exp. 3 (5)	Exp. 4 (6)	Exp. 5 (6)
> 4.8	0.1 ± 0.1	0.1 ± 0.2	0.0 ± 0.0	0.2 ± 0.3	0.4 ± 0.4
< 4.8 > 3	0.9 ± 1.5	0.2 ± 0.2	9.4 ± 1.7		
< 3 > 2	5.9 ± 3.7	12.2 ± 2.8			
< 2 > 1	10.4 ± 2.5				
< 1	0.2 ± 0.3	0.6 ± 0.9	7.2 ± 0.9	14.5 ± 1.7	
Mean consumption per group	17.5 ± 2.8	13.0 ± 2.8	16.6 ± 0.9	14.0 ± 1.3	0.4 ± 0.4

7.3.2 Field tests of whole maize as a deterrent for small granivorous birds.

Numbers of ostriches being fed at the Katkop feedlot dropped dramatically after January 1998, but crushed maize remained plentiful until the end of April when the last slaughter ostriches were sold. A number of alternative sources of crushed maize were available within a 2.5 km radius of the ostrich feedlot at this time including a cattle feedlot, a dairy, maize stubble and cattle and ostrich feedlots on the neighbouring farm, Lowlands Estate. Ringing results (Chapter 4) show that quelea and Red Bishops captured at the Katkop ostrich feedlot were among the several thousand birds utilising these resources in the following months. In June most of the Katkop cattle were sent to market and a new group of ostriches were introduced into the Katkop ostrich feedlot. However, these ostriches were fed only whole maize in their ration and while thousands of quelea and bishops continued to utilise the various sources of crushed maize in the area between May 1998 and June 1999, numbers at the Katkop ostrich feedlot remained low (Figure 4.2).

In contrast Laughing Doves, which are able to utilise the whole maize kernels, began to increase at the feedlots in September and showed their expected summer peak (Figure 6.6). By November 1998, 92% of the more than 300 doves seen in the study site were feeding in the ostrich feedlot.

7.3.3 Repellency of orange pulp in commercial ostrich feed to quelea.

Quelea in all treatments were weighed the same number of times and any effects of repeated handling on daily consumption would thus have been controlled for. The greatest drop in mean body mass of quelea (3-5%) was recorded after day four following the initial change in diet from mixed birdseed to one of crushed maize/crushed maize in ostrich feed (Table 7.2). Quelea in the control group that was maintained on birdseed throughout the experiment showed no corresponding drop in mass at the end of day four. This suggests that maize has a lower nutritional value than birdseed and/or that a period of adjustment is required before birds become accustomed to a new type of food.

Table 7.2 The effect of addition of orange pulp to commercial ostrich feed on the daily food intake of quelea, monitored indirectly by comparing daily measurements of body mass.

Treatment	n	Mean quelea body mass ± Standard deviation			
		Day 3 (Initial mass)	Day 4 (Diet change)	Day 5 (Final pre-treatment mass)	Day 6 (Post-treatment mass)
Mixed birdseed control	5	20.5 ± 1.1	20.4 ± 1.1	19.8 ± 1.2	20.8 ± 1.2
Crushed maize control	5	19.6 ± 1.9	18.6 ± 2.2	18.3 ± 1.8	18.8 ± 1.6
Untreated ostrich feed control	5	22.3 ± 1.7	21.7 ±1.5	21.2 ± 1.6	21.3 ± 1.8
Treated ostrich feed	20	22.1 ± 1.7	21.2 ± 1.7	20.7 ± 1.3	20.5 ± 1.5

Day-to-day fluctuations in body mass appear normal even for those quelea fed birdseed. Some individuals experienced mass changes of up to 1.5 g (7.7%) and similar weight fluctuations were recorded for birds fed only untreated crushed maize. In contrast, mean body mass of quelea in the experimental groups dropped less than one percent after 60% orange pulp was added to their feed. This implies that once quelea have become accustomed to eating maize, in the absence of alternative more suitable food sources, orange pulp does not deter feeding.

7.3.4 Repellency of crushed maize treated with orange rind and juice to quelea.

During preliminary experiments when quelea were presented with two identical containers of untreated crushed maize, they ate freely from both sources (Table 7.3). In all subsequent choice experiments birds ate significantly more of the untreated maize (ANOVA, P <0.001). 20% orange juice acted as the greatest feeding deterrent and only 5% of daily intake was obtained from the treated container. Orange rind was slightly less of a deterrent than juice, but consumption of treated maize was below 15% of daily intake in all experiments. Orange rind was an equally effective deterrent at 20% and 5% concentration and there was no apparent habituation to the orange maize mixture, despite testing the same eight birds at all concentrations. In the absence of an alternative more palatable food source, however, orange rind did not deter feeding even at the 20% concentration level.

Table 7.3 The effect of adding different concentrations of orange juice and rind to crushed maize on consumption by quelea in choice and no-choice tests. Sample sizes are given in parentheses. (EWL = Evaporative waterloss; SD = Standard deviation).

Treatment	Mean consumption of treated feed corrected for EWL ± SD (8)	Mean consumption of untreated feed ± SD (8)	Mean total feed consumption ± SD (8)	Mean EWL from treated controls ± SD (5)
Untreated maize	2.57 ± 0.74	1.98 ± 1.12	4.55 ± 0.62	
20 % orange juice in maize (choice)	0.22 ± 0.28	4.10 ± 0.58	4.6 ± 0.90	1.5 ± 0.05
20% orange rind in maize (choice)	0.58 ± 0.50	3.76 ± 0.84	4.31 ± 0.46	1.02 ± 0.46
10 % orange rind in maize (choice)	0.46 ± 0.80	4.21 ± 0.46	4.67 ± 0.35	0.81 ± 0.03
5 % orange rind in maize (choice)	0.66 ± 0.89	3.86 ± 1.09	4.57 ± 0.44	0.60 ± 0.04
20 % orange rind in maize (no-choice)	4.75 ± 0.74		4.75 ± 0.74	2.59 ± 0.03

7.3.5 Determination of the most effective concentration of alpha-chloralose for quelea.

None of the control animals showed any ill effects and remained alert and active throughout the experiments. All birds fed bait treated with the highest concentration of alpha-chloralose (2.5%) became at least partially immobilised while all birds fed the lowest concentration (0.5%) recovered (Table 7.4). Shortest mean immobilisation times, calculated only for individuals that became totally immobilised, were obtained at concentrations of 1.0 and 1.5% alpha-chloralose. The low survival of quelea fed 1% alpha-chloralose is therefore unexpected since relatively rapid immobilisation should have minimised the risks of individuals overdosing. The most effective concentration of alpha-chloralose for use against quelea was 1.5%, producing a high percentage immobilization, relatively rapid action and good survival of affected individuals. Percentage survival was important as a measure of how well non-target species might be expected to respond to treatment after eating alpha-chloralose bait. No increase in percentage total immobilization was achieved by increasing the concentration above 1.5%. All birds that recovered from alpha-chloralose treatment were eventually released back into the large outdoor cage where their condition was monitored further for several weeks. None of these birds died and all were eventually ringed and released where they were captured.

Table 7.4 The effect of different concentrations of alpha-chloralose on quelea. (SD = Standard deviation).

Concentration	% Total immobilisation	% Partial immobilisation	Mean time to total immobilization (min) ± SD	% Recovery of immobilised & partially immobilised birds	n
0.5 %	50	30	24.0 ± 9.6	100	10
1.0 %	70	20	15 ± 6.5	56	10
1.5 %	90		15.8 ± 8.9	78	10
2.0 %	90		22 ± 8.5	67	10
2.5 %	89	11	17.9 ± 10.2	78	9

7.3.6 The effect of quantity of bait consumed on quelea survival.

Only six out of the 19 quelea with above average consumption for a particular concentration of alpha-chloralose bait died during the experiments to determine the MEC (Table 7.5). A further 5 quelea with below average bait consumption also died during these experiments. This suggests that the condition of individual birds is likely to be a more important factor in determining the effectiveness of a particular concentration of alpha-chloralose than the quantity of bait consumed. It must also be taken into consideration that the amount of bait eaten does not necessarily translate into a measurable effective dosage. Some of this bait, 58% in one individual, may be stored in the non-absorptive oesophagus where alpha-chloralose is not thought to contribute to the narcotic effect (Ridpath *et al.* 1961).

Table 7.5 Mean mass of bait consumed by quelea in each treatment and number of individuals with above average consumption and the number of these individuals that died. (SD = Standard deviation).

Concentration	Mean mass (g) of bait consumed by quelea ± SD	n	No. of quelea with above average consumption	No. of quelea with above average consumption that died
0.5 %	0.37 ± 0.26	9	3	0
1.0 %	0.41 ± 0.28	9	3	1
1.5 %	0.31 ± 0.20	9	3	2
2.0 %	0.32 ± 0.19	9	5	3
2.5 %	0.28 ± 0.15	9	5	0

7.3.7 Intra-specific differences in susceptibility to alpha-chloralose.

Although samples sizes were too small to draw any definite conclusions, adult female and juvenile quelea generally appeared to be more susceptible to alpha-chloralose than adult males, becoming immobilized faster at all concentrations except 2.5% (Table 7.6). Only males showed a consistent decrease in immobilization time with increased concentration of alpha-chloralose, although there was no difference between 1.5% and 2.0%. There appeared to be little difference in the mortality rate of totally immobilized birds between male (33%) and female (37%) quelea. Four male quelea and seven females died from eating alpha-chloralose bait, but surprisingly, all immobilized juveniles recovered completely.

Table 7.6 Mean time to total immobilization for the different age/sex categories of quelea under each alpha-chloralose treatment. Sample sizes are given in parentheses. (SD = standard deviation).

Concentration	Immobilization time (minutes) ± SD		
	Adult male	Adult female	Juvenile
0.5 %	No immobilization	22.5 ± 9.6 (4)	27.0 (1)
1.0 %	24.0 (1)	14.2 ± 6.0 (5)	10.0 (1)
1.5 %	22.5 ± 9.9 (4)	10.0 ± 1.7 (3)	11.0 ± 1.4 (2)
2.0 %	22.5 ± 6.2 (4)	19.3 ± 12.9 (3)	19.0 ± 12.7 (2)
2.5 %	17.7 ± 7.1 (3)	17.5 ± 11.3 (4)	33.0 (1)

7.3.8 The effect of delayed treatment on bird survival.

There was no significant difference between the proportion of recoveries and mortalities between the three treatments (χ^2=1.90; df=1; P=0.17). However, while quelea left untreated for 60 minutes after becoming immobilised showed the same percentage recovery as those that were treated immediately (Table 7.7), individuals left untreated for 30 minutes showed the best rate of recovery. This may well be incidental, since the overall recovery rate of 77% was almost identical to the 78% obtained for birds fed 1.5% alpha-chloralose in the initial trials, when all birds were treated immediately (Table 7.4).

Table 7.7 The effect of delayed treatment of stupefied quelea on recovery.

Treatment	% Recovery	n
1.5% alpha-chloralose, immediate treatment	70	10
1.5% alpha-chloralose, 30 min delay	90	10
1.5% alpha-chloralose, 60 min delay	70	10
Overall % recovery	77	

7.3.9 Effect of alpha-chloralose on other bird species at feedlots.

All species were more sensitive than quelea and showed 100% total or partial immobilization at 1.5% alpha-chloralose (Table 7.8). Red Bishops and the two species of starling were the most sensitive and became immobilised in less than ten minutes. Recovery levels were acceptable in most species, but less than 50% of Red Bishops, Cape Sparrows and Wattled Starlings survived. Rock Pigeons appear to be the least sensitive to alpha-chloralose despite having a prolonged recovery period. Except in the case of Rock Pigeons that took up to 72 hours to recover, all individuals of the various species that recovered from the immobilizing effects of alpha-chloralose did so within 24 hours.

Table 7.8 The effect of 1.5% alpha-chloralose on some other species likely to consume treated bait at ostrich feedlots. (SD = Standard deviation).

Species	% Total immobilisation	% Partial immobilisation	Mean time to total immobilization (min) ± SD	% Recovery of immobilised & partially immobilised birds	n
Red Bishop	100		8.8 ± 5.0	17	6
Cape Sparrow	100		18.9 ± 18.1	44	9
Masked Weaver	100		10.3 ± 1.0	56	9
Spotted-backed Weaver	86	14	21.5 ± 13	71	7
Laughing Dove	100		32.0 ± 10.2	56	9
Rock Pigeon	100		45.8 ± 14.3	100	4
Wattled Starling	100		6.7 ± 5.6	33	6
Pied Starling *	83	17	approx. 9 min	83	6

* From field experiments with alpha-chloralose

7.3.10 Field experiments with alpha-chloralose.

In total 178 stupefied birds were retrieved from the feedlots after the two baiting sessions (Table 7.9). Quelea constituted the greatest proportion of these on both days while the remainder consisted of a variety of species commonly seen utilising the feedlots. Most drugged birds were still alive when discovered, but many dead quelea were found. Two Laughing Doves had been partially eaten and although the predator(s) could not be identified, they were most likely mongoose. A Small Grey Mongoose *Galerella pulverulenta* was later seen stalking a third partially immobilised dove and many more drugged birds are likely to have been scavenged. Small Grey Mongooses and Yellow Mongooses *Cynictis penicillata* were frequently seen in the feedlots and regularly took birds out of mistnets (pers. obs.). Suricates *Suricata suricatta*, Vervet Monkeys *Cercopithecus aethiops* and domestic cats are relatively uncommon, with the last-named apparently preferring to remain close to buildings. No ostriches were seen eating drugged birds, but some of the quelea that became immobilised in occupied ostrich camps had been trampled.

Table 7.9 Results of baiting with 1.5% alpha-chloralose in crushed maize at the Riverside Farm ostrich feedlot.

Species	Number immobilised per day		Total for each species	Total % recovery for each species
	Day 1	Day 2		
Laughing Dove	2	5	7	43
House Sparrow		1	1	100
Cape Sparrow		2	2	0
Quelea	37	119	156	20
Red Bishop	3	2	5	0
Pied Starling	6		6	83
Grey-headed Sparrow	1		1	0
Total for all species	49	129	178	23

Birds that ate the treated bait went through various stages of narcosis before becoming immobilised. The uncoordinated flight, stumbling and inability to perch of drugged birds did not appear to affect the feeding activities of other birds in the flocks at the bait site and these findings are supported by Cyr (1977). The degree of narcosis varied greatly between individuals of the same species.

7.3.11 Dispersal of stupefied birds.

Most stupefied birds were recovered at the bait site (42.7%) or at alternative feeding sites (38.2%). Only 7.9% of birds were found in known day (secondary) roosts while the remaining 11.2% of birds were found along roads and in the surrounding unoccupied ostrich pens. All birds were found within 300 m of the bait site with 77% of them less than 20 m from the bait (Figure 7.1).

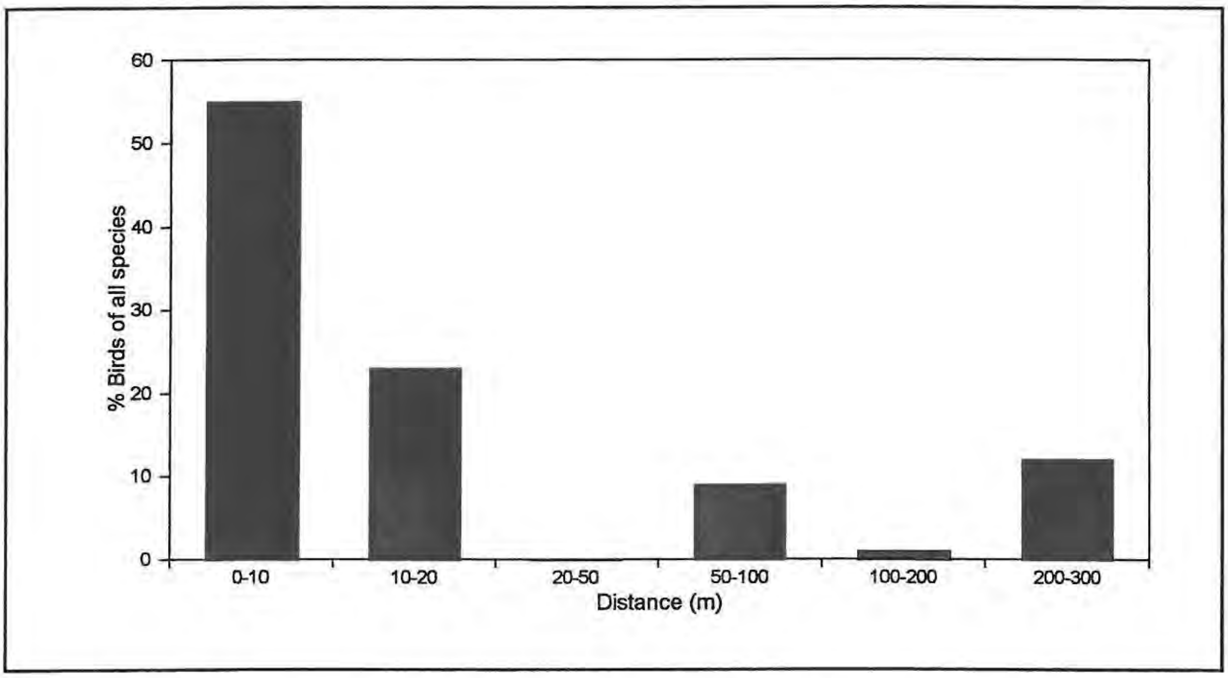


Figure 7.1 Distances from the bait site at which stupefied birds were recovered.

7.3.12 Effectiveness of the baiting operation.

Combined total counts of quelea at the Riverside Farm feedlot were 2355 and 2455 respectively on the two mornings prior to baiting and 2564 after baiting. Given the relative inaccuracy of the counting method and the small scale of the control operation (only one of three major feedings points was baited), the absence of any noticeable impact on numbers of birds estimated to be utilising the feedlot at Riverside Farm is not surprising. Assuming an initial population of around 2400 quelea, 6.5% of the total population were removed during the two mornings of baiting. In total, 10.5 hours were spent in bait preparation, laying bait, monitoring the bait site and searching for drugged birds over the two days.

7.4 DISCUSSION

Size preference trials confirmed field observations that although quelea prefer seeds 1-2 mm in diameter, when these are in short supply both larger and smaller grains will be taken (Ward 1973a). Descending preference tests showed that crushed maize >4.8 mm in size (including whole maize) could not be utilised by quelea, while finely crushed maize reduced daily consumption possibly because it takes longer to eat. European Starlings preferred ground barley to crushed in choice tests, but when it was mixed with silage it became more difficult to selectively remove the high protein component and crushed barley was then preferred (Feare & Wadsworth 1981; Feare *et al.* 1981). The increased foraging time needed to exploit finely crushed maize in a lucerne mixture might well deter quelea from feeding at ostrich feedlots when alternative food is available. The loss of the maize to wind is, however, likely to counteract any benefits. Use of whole maize in ostrich feed effectively removes this as a food source for quelea and other small granivorous birds, although Laughing Doves and Rock Pigeons are still capable of utilising it. Rock Pigeons only exploited the feedlots sporadically and while doves were present throughout the year, their numbers remained relatively low.

In situations where dominant ostriches appear to be removing whole maize at the expense of the growth of weaker individuals, alternating periods of crushed and whole maize may still be effective at limiting quelea population build-up at feedlots, without negatively affecting growth rates, especially when alternative food sources are available. During winter when natural food is scarce and quelea are most dependent on the feedlots, increasing maize size for even a short period could provide sufficient stimulus for quelea to move elsewhere in search of better foraging. This is likely to be the most cost-effective approach to limiting the impact of small granivorous birds at feedlots, since it requires no addition to the standard ration and whole maize is cheaper than crushed maize.

Pelleted foods have also been tested at ostrich feedlots and although more expensive (A.Roets, pers. comm.), they appear to provide a number of advantages which may well offset any additional costs. Most importantly, ostriches are ensured of a balanced ration that is no longer affected by wind blowing away the finer feed constituents or birds removing maize. By making pellets larger than is acceptable to most birds, overall loss of feed to problem birds may also be reduced (Feare *et al.* 1986; Johnson & Glahn 1994; M. Jarvis, pers. comm.). Despite this, certain species such as the weavers are still able to exploit ostrich feed by breaking pellets into acceptable sizes. Quelea are known to crack wheat and mature sorghum into smaller pieces before swallowing them (Jarvis & Vernon 1989a) and there is therefore no reason to assume they will be unable to do the same with feed pellets.

Ward (1979) maintains that quelea prefer natural grasses to cereal crops and only become a problem when natural food is scarce. Thus for any control strategy to be successful it must be effective in the absence of alternative food sources. In the presence of more palatable food sources, mixing orange with maize in the ostrich ration was repellent to quelea although the reason for this is not yet understood. Where it is important to feed crushed rather than whole maize, as with young ostriches, feed additives might be more appropriate. The addition of orange pulp to dairy feed is considered to have nutritional benefits and may therefore even enhance the growth rate of young ostriches. Young ostriches are more easily trained to eat relatively unpalatable foods (e.g. Sisal) than adult birds (M. Biggs, pers. comm.) and they should readily accept food treated with orange. Orange pulp is a natural, non-toxic repellent and should be exempt from the expenses and regulations usually involved with repellent registration. Even at the 20% concentration level, the additional costs of adding orange pulp to ostrich feed were estimated at less than 2c per ostrich per day. This is minimal compared to the estimated daily losses of maize to quelea and other problem birds (Chapter 6).

The use of repellents is frequently only a temporary solution to problems of bird depredation. Birds are often simply displaced to nearby unprotected crops/feedlots and rapidly re-invade once treatments are stopped (Glahn *et al.* 1989). Where commercial repellents are involved, long-term use may be uneconomical, but intermittent treatments may still prove beneficial and cost-effective (Glahn *et al.* 1989).

Factors limiting population size in large mobile populations are thought to substitute each other rather than be additive (Feare 1984). Consequently, for lethal control to succeed as a means of overall population reduction, more birds must be killed than would die naturally. This is rarely possible or desirable, and the more realistic approach of damage reduction through control of localised populations has therefore been adopted (Murton *et al.* 1964b; Murton *et al.* 1972; Ward 1973a; Murton *et al.* 1974; Bucher & Bedano 1976; Ward 1979; Jarvis 1983; Feare 1984; Jaeger 1992). By controlling birds at feedlots using alpha-chloralose, only those birds responsible for economic losses are removed. Where populations are relatively stable for extended periods small-scale local control is possible (Thearle 1969; Cyr 1977). However, immigration from surrounding areas is usually rapid (Murton *et al.* 1972; Murton *et al.* 1974; Feare *et al.* 1981; Dolbeer 1986).

Bait treated with 1.5% alpha-chloralose is the most effective for quelea control, but also affects the entire range of species likely to eat treated bait. This is to be expected given that 1.5% alpha-chloralose was also considered the most effective concentration for use against Feral Pigeons, when tested over the same range (Ridpath *et al.* 1961). Sensitivity varies considerably both inter-specifically and intra-specifically (Murton *et al.* 1963; Murton *et al.* 1965; this study) and while a lower concentration of alpha-chloralose is recommended for the 94-122 g Common Grackle *Quiscalus quiscula* (Cyr 1977) a higher concentration is more effective against the smaller 20.3-32.8 g House Sparrow (Cornwell 1966). These findings support the conclusion that while the effectiveness of alpha-chloralose may be directly related to body mass within species (Cyr & Brunet 1992), differences in size and gut anatomy alone cannot explain inter-specific differences in susceptibility to alpha-chloralose (Murton *et al.* 1963).

Female and juvenile quelea appeared more susceptible to the lower concentrations of alpha-chloralose than adult males and generally became immobilized faster at all concentrations. No sex-related differences were, however, found in Feral Pigeons and Mallards *Anas platyrhynchos* (Woronecki *et al.* 1992), and it is suggested that the differences between male and female Canada Geese *Branta canadensis* in the same study may be an artifact of small sample size (Belant and Seamans 1997). Small sample sizes may well have had a similar effect in this study. Young birds are considered more sensitive to toxins than older ones (Hill & Camardese 1981, in Brunet *et al.* 1996; Hudson *et al.* 1984, in Brunet *et al.* 1996), so it is surprising that all juvenile quelea recovered from alpha-chloralose treatment when a number of adults of both sexes did not. Low temperatures enhance the effects of alpha-chloralose (Giban *et al.*

1966, in Cyr 1977) and may improve capture success in some species (Stouffer & Caccamise 1991), while increasing mortality in others (Cyr 1977).

While percentage immobilization of quelea increased with alpha-chloralose concentration (up to 1.5%), bait consumption is thought to be the factor that ultimately determines whether birds consume sub-immobilising, effective, or lethal dosages (Murton *et al.* 1965; Gregory & Wilkins 1997). Despite this, only 6 out of 11 quelea that died had above average consumption for that concentration group suggesting that the condition of individual birds may be the most important factor determining the effects of a given concentration of bait. Duration of immobilization was related to the amount of bait consumed in studies with the Common Grackle (Cyr 1977) and, although not accurately recorded in this study, it may vary considerably. Recovery appears to be delayed by the passage of stored bait from the crop to the gizzard where alpha-chloralose can be absorbed into the bloodstream (Murton *et al.* 1965). The Rock Pigeons in this study stored large amounts of treated bait in their crops before becoming immobilised and this may explain their prolonged narcosis.

Under field conditions, additional factors influence bait consumption and its effect on the birds. The timing and amount of bait eaten relative to non-treated food will affect the speed of action and effectiveness of the alpha-chloralose. Alpha-chloralose bait is most effective when eaten on an empty stomach since the drug is then absorbed immediately (Crider *et al.* 1968, in Cyr & Brunet 1992). Those quelea which feed elsewhere prior to consuming bait, or feed on the bait intermittently are likely to experience a delay in the onset of narcosis since alpha-chloralose is first stored in the non-absorptive crop region, passing into the gizzard only when it has emptied. Stupefied birds were still found at the bait site several hours after the last bait had been removed and the area had been thoroughly checked four times.

More experiments are needed with quelea to determine the real effects of size (mass), sex, moult stage, bait intake and ambient temperature on speed of immobilization and recovery. Cold or food stressed birds, birds undergoing energetically expensive moult and juveniles are predicted to be more susceptible to alpha-chloralose, and lower concentrations of alpha-chloralose may therefore be more appropriate in winter, or after the breeding season when more juveniles are present and adults are in moult.

Preliminary field trials with alpha-chloralose produced promising results. Although capture success of 6.5% of the estimated total quelea population at the feedlot was low in comparison to 50% for European Starlings (Feare *et al.* 1981), 24% of the 500 birds estimated to have fed near the bait on the second day were immobilised. This compares more favourably with the 37% capture success achieved by Cyr (1977) during preliminary field trials with Common Grackles, despite using less bait and a smaller bait area.

All species that consumed the treated bait contribute to the overall loss of the maize component of the ostrich diet and thus can be considered legitimate targets. Pied Starlings are, however, also responsible for the removal of large numbers of ants which irritate ostriches (A. Roets, pers. comm.) and are potentially the most useful of the affected species. It is fortunate that they appear to recover well.

It is unlikely that birds will feed exclusively on treated bait even if pre-baiting is successful, but capture success can be improved by increasing the amount of bait and the area covered (Murton *et al.* 1963). This also makes bait more difficult to monitor, increasing the risk of primary poisoning of non-target species, and more difficult to remove after baiting (Murton *et al.* 1963; Caithness 1968; Cyr 1977). Alpha-chloralose bait is very stable and can remain viable for several weeks under field conditions (Murton *et al.* 1963; Caithness 1968). It is therefore essential that all bait is removed after a control operation. Where larger species are targeted for control, the use of whole maize as bait will prevent smaller birds from being affected.

Transferring ostriches to unoccupied camps for several days to allow baiting to take place at established feeding sites, provided that bait is laid in such a way that it can all be removed after the control operation (to ensure that no ostriches consume alpha-chloralose), may increase the likelihood of quelea feeding predominantly on treated bait. Similarly, Thearle (1969) found that baiting at established Wood-pigeon *Columba palumbus* feeding sites was preferable to pre-baiting, which was usually unsuccessful. Increasing the baiting period, though likely to increase capture success, also increases the risk that birds may have eaten prior to taking bait.

The most serious environmental risk of alpha-chloralose baiting is the threat of secondary poisoning of animals that eat stupefied birds. Herons and many other scavengers may swallow food whole, and while raptors at least do not eat the crop contents of their prey, the length of time that alpha-chloralose remains effective in the bloodstream of stupefied birds is unknown (Brunet *et al.* 1996). Limiting the dispersal of stupefied birds and improving their collection can reduce risks of secondary poisoning.

Decreasing the immobilization time should reduce the distance birds can travel before becoming immobilised. Laboratory trials showed that the onset of narcosis is most rapid at intermediate concentrations, and therefore the effectiveness of bait cannot be enhanced by simply increasing the concentration of alpha-chloralose. More rapid immobilization can, however, often be obtained with mixtures of drugs (Thearle 1969; Cyr & Brunet 1992) and attempts have been made to improve the action of alpha-chloralose. Feare *et al.* (1981) found that quinalbarbitone sodium (seconal) in combination with alpha-chloralose reduced dispersal of stupefied European Starlings, but one individual was still found approximately 1 km from the bait site. Alpha-chloralose and secobarbital combinations also improved bait effectiveness in laboratory trials (Cyr & Brunet 1992).

Usual movement patterns of quelea involve frequent flights from feed troughs to nearby trees, sometimes in response to raptors or other unnoticed disturbances. This behaviour is typical of flocks of small birds and can result in wide dispersal of sub-immobilised birds within the feeding area. Small birds are especially difficult to find once they have become immobilised (Williams & Phillips 1972). Consequently, it is essential that bait areas should be carefully selected with the collection of stupefied birds in mind. In certain situations it may be possible to alter the surroundings to improve the ease of spotting birds. For example tall weeds and long grass can be mowed in surrounding camps. The number of searchers should also be increased to suit the size of the operation being undertaken.

Most stupefied birds were found close to the baiting site and at known roosts and alternative feeding sites, possibly because these areas were the most thoroughly searched. Feare *et al.* (1981) suggest that this represents a minimum estimate of stupefied birds because some, especially those lying further from baiting sites, are likely to have been missed even after an intensive search effort. Fortunately, studies of quelea behaviour suggest that they tend to remain within a feeding area throughout the day provided the food supply lasts, and will utilise nearby trees as daytime roosts (Ward 1978). This favours limited dispersal of affected birds and, while not necessarily making collection easier, it helps to contain the contamination area to the immediate surroundings of the bait site.

Delayed treatment of affected birds did not appear to negatively affect their chances of survival. If the benefits of placing drugged birds in a warm, dark place to assist recovery from alpha-chloralose treatment are through the prevention of chilling (Cyr 1977) and the removal of unnecessary stimulation (Thomas *et al.* 1988), then stupefied birds lying in sheltered positions in outdoor cages might well receive the same benefits as birds placed in cloth bags. Delay in collection of stupefied birds might have a greater impact on survival under field conditions, where shelter and protection from predation cannot be ensured. Removal of unabsorbed alpha-chloralose through gastric lavage may also assist recovery (Cyr 1977; Thomas *et al.* 1988).

There appears to be general agreement that alpha-chloralose is a humane method of controlling problem animals and does not appear to cause stress (Borg 1955; Caithness 1968; Cyr 1977; Stouffer & Caccamise 1991; Woronecki *et al.* 1992), although high dosages may cause convulsions, torticollis and subsequently death (Loibl *et al.* 1988). Alpha-chloralose is therefore seen as a suitable replacement for less humane poisons (e.g. Strychnine) commonly used in bird control (Woronecki *et al.* 1990).

Some non-target mortality is inevitable in any form of control operation, and in certain situations, direct poisons such as DRC-1339 may be more appropriate than alpha-chloralose with its relatively high secondary poisoning risk. DRC-1339 has been successfully used in bait to remove starlings from various livestock feeding operations, with minimal effect to non-target species if normal precautions such as careful monitoring of bait sites are taken (Royall *et al.* 1967; West *et al.* 1967; West 1968; Dolbeer 1986). Although slow acting, allowing widespread dispersal of affected birds, it does not appear to pose a secondary poisoning threat to mammalian or avian predators (Royall *et al.* 1967). This is because the toxin is completely metabolised and excreted in a non-toxic form before the bird dies (Brooks & Hussain 1990).

Alternative methods of capturing birds such as traps and mistnets can also be effective means of control (Jarvis 1983; Dolbeer 1986). Decoy traps such as the Australian Crow trap and various modifications thereof have been used successfully for a variety of problem species around the world (Woodbury 1961; Bogatich 1967; Palmer 1972; Hussain 1990; Clark & Hygnstrom 1994; Hall 1994; Fitzwater 1994; Johnson & Glahn 1994; Gadd 1996). These cages can be easily constructed from farm scrap and if correctly sited and set up, they require little maintenance. The advantage of this method is that non-target birds can be released unharmed, while problem birds provide a useful additional food source for farm labourers. At Riverside Farm labourers plucked wing feathers and continued to fatten birds in an enclosed pen by providing scrap maize. These were then eaten (A. Roets, pers. comm.). The use of digitally recorded calls has increased trapping success of migrant species (Kearns *et al.* 1998) and may further enhance the attractive value of decoy birds.

Mistnets share many of the advantages of cage traps, but are unsuitable in windy or wet conditions. They are also considerably more labour intensive and trained operatives are required to remove entangled birds. Where damage occurs over a relatively small area or where the movements of birds are predictable and nets can be placed in a known flight path, mistnetting may be extremely successful (Jarvis 1983; Plesser *et al.* 1983). More than 700 quelea (approximately 20% of those estimated to be feeding) were ringed over a two-day period at the Katkop dairy and considerably less effort would have been required if birds were simply being killed rather than ringed and released. Greater numbers of quelea are captured where they concentrate at roost sites, and in certain countries millions may be harvested each year for food (Jaeger & Elliott 1989).

No single method of damage reduction is likely to be successful in all bird pest situations. A variety of factors including the biology of the species involved, the extent of the damage and the risk to non-target species should be weighed against the cost and likelihood of success of the proposed control strategy. There may be considerable local movement between farms, even among the relatively sedentary dry season flocks (Chapter 4). Consequently the use of alpha-chloralose at this time is likely to provide only short-term relief, since immigration from surrounding areas is likely to be rapid. Lethal control may be a more appropriate option when valuable crops are being protected, but in the absence of changes to the attractive source of food this is at best, only a temporary solution (Feare 1980). In most bird damage situations, non-lethal methods may prove to be both more effective and more economically viable. In the summer months, when quelea numbers are low and alternative food sources are available, orange rind may well prove an effective deterrent. While in winter, the introduction of whole maize into the ostrich ration, even for a short period, may produce an acute local food shortage sufficient to force quelea to move elsewhere (management options are summarised in Appendix 12).

GENERAL DISCUSSION

The main objectives of this study were firstly to determine the current distribution of quelea in the Eastern Cape and to assess whether the distribution and abundance of this species have changed in the region in recent decades. Secondly to determine if quelea in the Eastern Cape represent an isolated, sedentary population, or whether large scale interchange is occurring with other quelea populations in southern Africa. Thirdly to estimate the loss of stock feed to quelea and other granivorous birds at feedlots and to assess their dependence on this food source and fourthly to assess management options for reducing bird damage in this region.

8.1 DISTRIBUTION AND ABUNDANCE OF QUELEA

The South African Bird Atlas Project (SABAP) has greatly increased our knowledge of quelea distribution in the Eastern Cape Province. While comparison of SABAP maps with earlier published data suggests that quelea have expanded their range considerably since the 1980s (Chapter 3), it is likely that many of the SABAP records still reflect only chance sightings of the vagrant flocks which appear always to have visited this region (Skead 1965a). Obviously, as the number of observers increased one would expect more sightings (Ffrench 1967; Macdonald 1986), but this does not appear to be the whole explanation. In well-surveyed areas of the Eastern Cape, such as the Albany District, where quelea were previously seldom seen, they are now regular visitors at all times of year (Chapter 3).

Only a small proportion of the quelea population is thought to ever come into contact with agricultural crops (Ward 1973a) and their enormous numbers have been attributed mainly to their vast range and the abundance of their natural food i.e. seeds of perennial grasses (Ward 1964). Although quelea do appear to breed regularly in the Eastern Cape (Chapter 4), records suggest that these colonies are relatively small and in the absence of a widespread abundant supply of natural grass seed in the region, local breeding is unlikely to be an important contributing factor to future population growth.

Rather, factors affecting breeding populations in more suitable habitat to the north are likely to be crucial.

If predictions of global warming are correct and conditions become increasingly arid in many areas, farmers may be forced to seek other more drought resistant cereal crops (Gates 1993). At present large areas of the Free State are planted to maize that does not appear to be damaged by quelea to any great extent. However, should more drought resistant sorghum be introduced, food available to quelea would be greatly increased. Areas of the Northern Province that were considered too arid for maize have experienced considerable damage to sorghum by quelea in the past and many farmers were forced to stop growing it (Naude 1959). Increased aridity is also likely to reduce the availability of natural grazing and thus increase the need for intensive rearing of livestock at feedlots. Both of these factors may benefit quelea and increase the size of the immigrant winter population in the Eastern Cape.

While mountain ranges, forest and arid Karoo may be thought to provide strong natural barriers to quelea expansion into the Western Cape, quelea were recorded at Zeekoei Vlei near Cape Town in 1946 (Gill 1970). This unusual sighting was attributed to an exceptional abundance of quelea in the northern parts of South Africa in that year (Gill 1970). An additional record of a male quelea trapped on a farm near Durbanville in the Western Cape (L.G. Underhill, SABIRDNET) as recently as February 2001 confirms that quelea are indeed capable of crossing formidable natural barriers. Whether quelea will eventually expand their range into the wheat fields of the Western Cape remains a matter for speculation, but a build-up of quelea numbers in the Eastern Cape may well provide the necessary impetus for further southward expansion. Wheat in the Western Cape is harvested in late spring and thus coincides with the period of quelea abundance in the Eastern Cape.

Quelea do not appear to be expanding their range in the obvious manner of the European Starling in North America (Cabe 1993), which is gradually spreading and occupying an increasingly large area over time. Rather, they appear to be vagrant over a wider area, penetrating further south and west into the Eastern Cape with a higher frequency of large flocks being reported than in the past (Chapter 3).

8.2 INCREASED SEDENTARINESS

In areas of suitable habitat and where food supplies are regular and predictable (e.g. where livestock feedlots are common) there is good evidence to suggest that quelea flocks may be more sedentary, at least during the dry season. There may nevertheless be considerable inter-change between adjacent sites. While the majority of quelea may still move north to breed, there appear to be at least some individuals that breed locally (Chapter 4; Chapter 5). Which birds move and which remain, and whether the same individuals behave in the same way each year has yet to be determined for quelea, but appears to be quite complex in species such as the European Starling (Kessel 1953; Suthers 1978; Glahn *et al.* 1987) and the Tasmanian Silvereye *Zosterops lateralis lateralis* (Chan & Kikkawa 1997). The situation may vary between years depending on the body condition and breeding readiness of individuals, and on environmental variables such as the timing and extent of local rains and their effect on local food availability.

Data on the proportion of quelea with pink streaks in the eyebrow stripe and of russi versus mask type individuals (Chapter 5), together with the observed influx of quelea into the Riverside Farm feedlot over the dry season (Chapter 4), some of which must have originated from breeding colonies to the north, support the concept of a single, integrated, quelea population in southern Africa. Samples from more non-breeding populations are, however, needed before the real value of the eyebrow markings can be determined. Given the low recovery rate of ringed quelea, such distinguishing characteristics have the potential to greatly improve our knowledge of the movement patterns of quelea during the non-breeding season. Mass marking techniques are nevertheless still necessary to elucidate quelea movement patterns on a finer spatial scale and further research in this field (e.g. Steele *et al.* 1999) should be encouraged.

If the quelea population in the Eastern Cape is comprised of distinct resident and "migratory" components, one might expect differences in breeding plumage to exist between locally breeding birds and other southern African populations, despite extensive mixing of different flocks during the dry season. However, if the decision to migrate is determined by local conditions and breeding readiness of individuals in a particular year, there is likely to be a regular exchange of individuals between the segment of the population which breeds locally and that which moves elsewhere. If the latter scenario is correct, then one would expect plumage characteristics to remain consistent throughout the whole southern African population.

Breeding males collected in the Eastern Cape appear generally pinker (i.e. a higher proportion of individuals have pink suffused plumage) than birds sampled from areas to the north (Chapter 5). While this suggests the possibility of a more resident breeding population, data from outside this region are old and may no longer accurately reflect the appearance of the populations of those areas. In light of the recent findings of Jones *et al.* (In press) and evidence of quelea moving between the Eastern Cape and the Free State, an isolated breeding population of this species in the Eastern Cape is not supported.

8.3 ESTIMATED FEED LOSS AND DEPENDENCE ON ARTIFICIAL FOOD SOURCES

Cultivation of wheat, the only small grain cereal crop grown to any extent in the Eastern Cape, is largely confined to a few relatively small areas along the Great Fish River and closer to the coast (Döhne Agricultural Development Institute, pers. comm.). Consequently, alternative artificial food sources, such as crushed maize, may have been crucial to quelea expansion into this region. Crushed maize comprises a large proportion of the quelea diet for much of the year (Chapter 6), but as in the Bergville-Winterton area of KwaZulu-Natal (Berruti 1995; Berruti 2000) it appears especially important in winter and spring when natural food is in short supply, and the energetically expensive processes of pre-nuptial and post-nuptial moult are undertaken. Economically significant damage is, however, not confined to the periods when quelea are most dependant on maize. Damage should be assessed in terms of whether it is economically viable to implement some form of control or damage reduction measure and this applies in all seasons.

The equation for estimating loss of stock feed (Chapter 6) provides a relatively quick and simple means of estimating feed losses to several granivorous species. In the absence of convenient alternative food sources, basic data such as the proportion of crushed maize in the birds diet and their daily consumption are likely to remain fairly constant throughout the major damage period. Thus, the only inputs that need to be generated by the farmer are an estimate of the number of problem birds and the market value of the feed. With relatively little practice some of the largest quelea flocks that are likely to be regularly encountered at feedlots can be estimated relatively accurately (Chapter 4). In this way the potential for damage can be regularly monitored to determine when action against problem birds is justified.

Although most quelea may not breed locally, a large proportion of the population remains in the dry season quarters until pre-nuptial moult is completed. This is not surprising considering the continued ready availability of food, but it appears to be a departure from the normal behaviour of this species in most areas (Jones 1989a; Jones *et al.* 2000). Thus, during the later stages of pre-nuptial moult, quelea may become a serious pest of ripening wheat in areas where previously an absence of suitable food during the dry season may have prevented a build-up of numbers. Even at current relatively low numbers, the presence of quelea flocks is preventing much needed agricultural diversification in a number of districts. The cultivation of high value crops such as birdseed and wheat are not considered viable because of the strong potential for severe damage (H. Olivier and A. Collett, pers. comm.).

During the late summer and autumn months quelea numbers at the feedlots are lowest. Grass and weed seeds are abundant at this time and dependence on maize is much reduced, although some individuals still obtain a large proportion of their food from the feedlots. This has important implications for management of this species.

8.4 MANAGEMENT OPTIONS

Methods of damage reduction tested in this study (Chapter 7) are relatively easy and inexpensive to implement and should produce good results. During summer and autumn alternative, more palatable, natural food sources may be available to quelea and thus manipulating the livestock ration, such as by adding orange pulp to the feed mixture, should prove effective in displacing problem birds onto natural food in the surrounding areas. This approach is, however, unlikely to be successful in winter and spring when little natural seed is available. During this period feeding whole rather than crushed maize for short periods will effectively eliminate feedlots as a source of food for all small granivores. This should in turn create sufficient food shortage for quelea to be forced to move off in search of alternative foraging areas. The distance that quelea may move is likely to depend on the availability of food on surrounding farms. With the co-operation of several farmers it should be possible to displace quelea from an area for a longer period, and this would provide relief for ripening cereal crops if timed correctly. Short periods of feeding whole maize are unlikely to affect the growth of adult ostriches to any extent, and chick pens are usually small enough to make netting a practical option for excluding quelea. During the winter months, Rock Pigeon numbers are at their lowest and thus apart from the Laughing Doves and possibly Wattled and Pied Starlings, none of the problem species will be able to utilise the ostrich feed. While pelleting of food has its merits in terms of ensuring a balanced diet to ostriches, this is a relatively expensive form of feeding and is unlikely to substantially reduce feed loss to pest birds.

Although alpha-chloralose bait appears to have good potential as a control agent, the value of lethal control in management of quelea populations at feedlots is questionable. As the dry season progresses and natural food supplies decrease, quelea tend to concentrate at the feedlots and the population size may continue to increase into spring. Thus any birds killed before quelea begin to depart at the start of the following breeding season are likely to be rapidly replaced by new arrivals at the feedlots. While it may be argued that lethal control will at least maintain numbers at a lower level and reduce overall damage, this is not necessarily true since low recapture rates of ringed birds suggests considerable movement between roosts and feeding sites within a general foraging area. Thus, in addition to the influx of new birds possibly from areas to the north, there is considerable local movement that may well serve to maintain high populations of quelea at good feeding sites. The question of the economic viability of prolonged control operations must also be considered. Increased sedentariness of quelea in this region still needs to be tested further, but is unlikely to affect management decisions for the foreseeable future. Greatest losses of feed occur during winter and spring and are likely to be mainly the result of large flocks of immigrant quelea, rather than the relatively small local population.

Quelea have adapted their nomadic lifestyle to exploit the abundant and reliable food provided at feedlots and as long as feedlots continue to present food in a form attractive to quelea and other granivorous birds, the problem is likely to remain. Removing or enclosing feedlots is not a practical solution, but using our knowledge of the feeding preferences and behaviour of quelea, it is possible to alter the way in which stock food is presented so as to render it less attractive to them. In this way feed loss can be reduced in an economically viable and sustainable manner, without detriment to the environment and to non-target species.

APPENDICES

APPENDIX 1

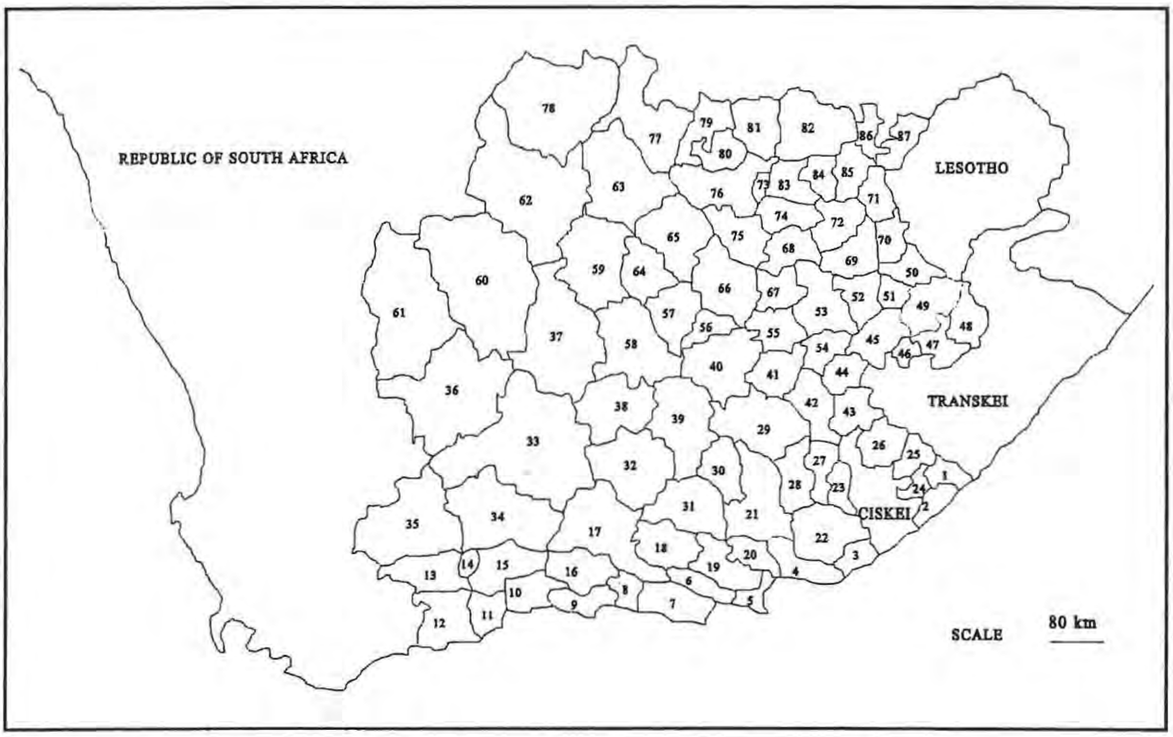
List of common and scientific names of bird species mentioned in the text. Species are arranged in alphabetical order according to common name. For southern African species, scientific names follow Maclean (1993) while for remaining species the cited reference is followed.

Common name	Scientific name
Black widow-finch	*Vidua funerea*
Brown-headed Cowbird	*Molothrus ater*
Canada Goose	*Branta canadensis*
Cape Sparrow	*Passer melanurus*
Cape Turtle Dove	*Streptopelia capicola*
Cape Weaver	*Ploceus capensis*
Chaffinch	*Fringilla coelebs*
Collared Dove/ Collared Turtle Dove	*Streptopelia decaocto*
Common Grackle	*Quiscalus quiscula*
Dickcissel	*Spiza americana*
Eared Dove	*Zenaida auriculata*
European Starling	*Sturnus vulgaris*
Feral Pigeon	*Columba livia*
Grey-headed Sparrow	*Passer griseus*
Helmeted Guineafowl	*Numida meleagris*
Horned Lark	*Eremophilia alpestris praticola*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
Indian Myna	*Acridotheres tristis*
Lanner Falcon	*Falco biarmicus*
Laughing Dove	*Streptopelia senegalensis*
Little Corella	*Cacatua pastinator*
Mallard	*Anas platyrhynchos*
Masked Weaver	*Ploceus velatus*
Namaqua Dove	*Oena capensis*
Palm Dove	*Streptopelia senegalensis*
Partridge	*Perdix perdix*
Picazuro Pigeon	*Columba picazuro*
Pied Barbet	*Tricholaema leucomelas*
Pied Starling	*Spreo bicolor*
Red-billed Firefinch	*Lagonosticta senegala*
Red-billed Quelea	*Quelea quelea*

APPENDIX 1 continued

Common name	Scientific name
Red Bishop	*Euplectes orix*
Red-collared Widow	*Euplectes ardens*
Red-eyed Dove	*Streptopelia semitorquata*
Red-headed Finch	*Amadina erythrocephala*
Red-headed Quelea	*Quelea erythrops*
Red-shouldered Widow	*Euplectes axillaris*
Red-winged Blackbird	*Agelaius phoeniceus*
Rock Pigeon	*Columba guinea*
Rook	*Corvus frugilegus*
Spotted-backed Weaver	*Ploceus cucullatus*
Spot-winged Dove	*Columba maculosa*
Stock Dove	*Columba oenas*
Tasmanian Silvereye	*Zosterops lateralis lateralis*
Turtle Dove	*Streptopelia turtur*
Wattled Starling	*Creatophora cinerea*
Wood Pigeon	*Columba palumbus*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*

APPENDIX 2



Magisterial Districts of the Eastern Cape Province and surrounding areas.

Key to Magisterial Districts

1 Komga, 2 East London, 3 Bathurst, 4 Alexandria, 5 Port Elizabeth, 6 Hankey, 7 Humansdorp, 8 Joubertina, 9 Knysna, 10 George, 11 Mosselbay, 12 Riversdale, 13 Ladismith, 14 Calitzdorp, 15 Oudtshoorn, 16 Uniondale, 17 Willowmore, 18 Steytlerville, 19 Uitenhage, 20 Kirkwood, 21 Somerset East, 22 Albany, 23 Fort Beaufort, 24 King William's Town, 25 Stutterheim, 26 Cathcart, 27 Adelaide, 28 Bedford, 29 Cradock, 30 Pearston, 31 Jansonville, 32 Aberdeen, 33 Beaufort West, 34 Prince Albert, 35 Laingsburg, 36 Fraserburg, 37 Victoria West, 38 Murraysburg, 39 Graaff-Reinet, 40 Middelburg, 41 Hofmeyr, 42 Tarka, 43 Queenstown, 44 Sterkstroom, 45 Wodehouse, 46 Indwe, 47 Elliot, 48 Maclear, 49 Barkley East, 50 Transkei enclave, 51 Lady Grey, 52 Aliwal North, 53 Albert, 54 Molteno, 55 Steynsburg, 56 Noupoort, 57 Hanover, 58 Richmond, 59 Britstown, 60 Carnarvon, 61 Williston, 62 Prieska, 63 Hopetown, 64 De Aar, 65 Philipstown, 66 Colesburg, 67 Venterstad, 68 Bethulie, 69 Rouxville, 70 Zastron, 71 Wepener, 72 Smithfield, 73 Jagersfontein, 74 Trompsburg, 75 Philippolis, 76 Fauresmith, 77 Herbert, 78 Hay, 79 Jacobsdal, 80 Koffiefontein, 81 Petrusburg, 82 Bloemfontein, 83 Edenburg, 84 Reddersburg, 85 Dewetsdorp, 86 Botshabelo, 87 Ladybrand.

APPENDIX 3

Details of all recaptures and recoveries of quelea ringed at Fort Brown, Fish River and Cookhouse. Data are organised according to district, ring number and then date. * Indicate recapture/recovery and ** indicate a second recapture of the same individual. For those individuals recaptured a second time, the time elapsed since first recapture is given in parentheses. (AD=adult, J=juvenile, J?=suspected juvenile, M=male, F=female, NB=non-breeding plumage and could not be sexed).

Capture locality	Date of capture/recapture			Ring number	Age/sex	Distance travelled (km)	Time elapsed (days)
	Day	Month	Year				
Brandeston	14	8	97	AE65215	AD/NB		
Brandeston	27	10	97	AE65215*	AD/NB	0	74
Katkop (Ostriches)	28	9	97	AD51410	AD/NB		
Katkop (Cattle)	3	6	98	AD51410*	AD/NB	0.2	278
Katkop (Maize)	30	7	98	AD51410**	AD/NB	0	335 (57)
Katkop (Dairy)	16	6	99	AD51973	AD/NB		
Lowlands Estate	20	8	99	AD51973*	AD/NB	1.3	65
Katkop (Dairy)	16	6	99	AD51983	AD/NB		
Lowlands Estate	20	8	99	AD51983*	AD/NB	1.3	65
Katkop (Ostriches)	28	7	97	AE65204	AD/NB		
Katkop (Maize)	29	8	98	AE65204*	AD/NB	0.2	397
Katkop (Ostriches)	29	10	97	AF00058	AD/F		
Katkop (Dairy)	30	5	99	AF00058*	AD/NB	1.5	578
Katkop (Ostriches)	26	2	98	AF24016	AD/M		
Katkop (Cattle)	3	6	8	AF24016*	AD/NB	0.2	97
Katkop (Ostriches)	26	2	98	AF24017	J?		
Katkop (Cattle)	25	6	98	AF24017*	NB	0.2	119
Katkop (Cattle)	3	6	98	AF24180	AD/NB		
Lowlands Estate	31	10	98	AF24180*	AD/M	3	150
Katkop (Cattle)	3	6	98	AF24206	AD/M		
Katkop (Maize)	30	7	98	AF24206*	AD/NB	0	58
Katkop (Cattle)	25	6	98	AF24310	AD/NB		
Katkop (Dairy)	30	5	99	AF24310*	AD/NB	1.7	339
Lowlands Estate	31	10	98	AF37930	AD/M		
Soutpansdrift	15	12	99	AF37930*	AD/NB	26	410
Lowlands Estate	31	10	98	AF37962	AD/M		
Katkop (Dairy)	21	8	99	AF37962*	AD/NB	1.3	294
Katkop (Dairy)	30	5	99	AF50569	AD/NB		
Lowlands Estate	21	8	99	AF50569*	AD/NB	1.3	83
Katkop (Dairy)	30	5	99	AF50576	AD/NB		
Katkop (Dairy)	16	6	99	AF50576*	AD/NB	0	17
Katkop (Dairy)	30	5	99	AF50586	AD/NB		

APPENDIX 3 continued

Capture locality	Date of capture/recapture			Ring number	Age/sex	Distance travelled (km)	Time elapsed (days)
	Day	Month	Year				
Katkop (Dairy)	16	6	99	AF50586*	AD/NB	0	17
Katkop (Dairy)	30	5	99	AF50635	AD/NB		
Katkop (Dairy)	22	8	99	AF50635*	AD/NB	0	84
Katkop (Dairy)	30	5	99	AF50637	J		
Katkop (Dairy)	16	6	99	AF50637*	NB	0	17
Katkop (Dairy)	30	5	99	AF50658	AD/NB		
Katkop (Dairy)	16	6	99	AF50658*	AD/NB	0	17
Katkop (Dairy)	30	5	99	AF50673	AD/NB		
Katkop (Dairy)	16	6	99	AF50673*	AD/NB	0	17
Katkop (Dairy)	30	5	99	AF50688	J		
Katkop (Dairy)	16	6	99	AF50688*	NB	0	17
Katkop (Dairy)	30	5	99	AF50691	AD/NB		
Katkop (Dairy)	17	6	99	AF50691*	AD/NB	0	18
Katkop (Dairy)	30	5	99	AF50706	AD/NB		
Katkop (Dairy)	16	6	99	AF50706*	AD/NB	0	17
Katkop (Dairy)	30	5	99	AF50718	J		
Katkop (Dairy)	17	6	99	AF50718*	NB	0	18
Katkop (Dairy)	30	5	99	AF50723	AD/NB		
Katkop (Dairy)	17	6	99	AF50723*	AD/NB	0	18
Katkop (Dairy)	30	5	99	AF50724	AD/NB		
Katkop (Dairy)	16	6	99	AF50724*	AD/NB	0	17
Katkop (Ostriches)	30	5	99	AF50743	AD/NB		
Katkop (Dairy)	17	6	99	AF50743*	AD/NB	1.5	18
Katkop (Dairy)	18	6	99	AF50743*	AD/NB	0	19 (1)
Katkop (Dairy)	30	5	99	AF50766	J		
Katkop (Dairy)	16	6	99	AF50766*	NB	0	17
Katkop (Dairy)	30	5	99	AF50799	AD/NB		
Katkop (Dairy)	16	6	99	AF50799*	AD/NB	0	17
Katkop (Dairy)	16	6	99	AF50854	AD/NB		
Katkop (Dairy)	17	6	99	AF50854*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF50882	AD/NB		
Katkop (Dairy)	17	6	99	AF50882*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF50893	AD/NB		
Katkop (Dairy)	21	8	99	AF50893*	AD/NB	0	66
Katkop (Dairy)	16	6	99	AF50894	AD/NB		
Katkop (Dairy)	17	6	99	AF50894*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF50897	AD/NB		

APPENDIX 3 continued

Capture locality	Date of capture/recapture			Ring number	Age/sex	Distance travelled (km)	Time elapsed (days)
	Day	Month	Year				
Katkop (Dairy)	17	6	99	AF50897*	AD/NB	0	1
Katkop (Dairy)	17	6	99	AF50930	AD/NB		
Katkop (Dairy)	21	8	99	AF50930*	AD/NB	0	65
Katkop (Dairy)	17	6	99	AF50961	AD/NB		
Katkop (Dairy)	21	8	99	AF50961*	AD/NB	0	65
Katkop (Dairy)	16	6	99	AF75501	AD/NB		
Katkop (Dairy)	17	6	99	AF75501*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF75507	AD/NB		
Katkop (Dairy)	17	6	99	AF75507*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF75520	AD/NB		
Katkop (Dairy)	18	6	99	AF75520*	AD/NB	0	2
Katkop (Dairy)	16	6	99	AF75527	J		
Katkop (Dairy)	17	6	99	AF75527*	J	0	1
Katkop (Dairy)	16	6	99	AF75561	J		
Katkop (Dairy)	17	6	99	AF75561*	J	0	1
Katkop (Dairy)	16	6	99	AF75584	AD/NB		
Katkop (Dairy)	17	6	99	AF75584*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF75588	AD/NB		
Katkop (Dairy)	21	8	99	AF75588*	AD/NB	0	66
Katkop (Dairy)	16	6	99	AF75641	AD/NB		
Katkop (Dairy)	17	6	99	AF75641*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF75663	AD/NB		
Katkop (Dairy)	17	6	99	AF75663*	AD/NB	0	1
Katkop (Dairy)	16	6	99	AF75690	AD/NB		
Katkop (Dairy)	21	8	99	AF75690*	AD/NB	0	66
Katkop (Dairy)	16	6	99	AF75695	AD/NB		
Katkop (Dairy)	17	6	99	AF75695*	AD/NB	0	1
Katkop (Dairy)	17	6	99	AF75737	AD/NB		
Katkop (Dairy)	21	8	99	AF75737*	AD/NB	0	65
Katkop (Dairy)	17	6	99	AF75747	AD/NB		
Katkop (Dairy)	18	6	99	AF75747*	AD/NB	0	1
Katkop (Dairy)	17	6	99	AF75771	AD/NB		
Katkop (Dairy)	18	6	99	AF75771*	AD/NB	0	1
Katkop (Dairy)	18	6	99	AF75854	AD/NB		
Lowlands Estate	20	8	99	AF75854*	AD/NB	1.3	63
Katkop (Dairy)	18	6	99	AF75868	AD/M		
Lowlands Estate	21	8	99	AF75868*	AD/NB	1.3	64

APPENDIX 3 continued

Capture locality	Date of capture/recapture			Ring number	Age/sex	Distance travelled (km)	Time elapsed (days)
	Day	Month	Year				
Katkop (Dairy)	18	6	99	AF75875	AD/NB		
Katkop (Dairy)	21	8	99	AF75875*	AD/NB	0	64
Katkop (Dairy)	17	6	99	AF75901	AD/NB		
Katkop (Dairy)	21	8	99	AF75901*	AD/NB	0	65
Katkop (Dairy)	17	6	99	AF75939	AD/NB		
Lowlands Estate	22	8	99	AF75939*	AD/NB	1.3	66
Katkop (Dairy)	17	6	99	AF75947	AD/NB		
Soutpansdrift	8	10	00	AF75947*	AD	26	478
Katkop (Dairy)	17	6	99	AF75953	J		
Katkop (Dairy)	21	8	99	AF75953*	J	0	65
Katkop (Dairy)	17	6	99	AF75998	AD/NB		
Katkop (Dairy)	21	8	99	AF75998*	AD/NB	0	65
Lowlands Estate	20	8	99	AF81010	AD/NB		
Lowlands Estate	22	8	99	AF81010*	AD/NB	0	2
Katkop (Dairy)	20	8	99	AF81023	AD/NB		
Katkop (Dairy)	21	8	99	AF81023*	AD/NB	0	1
Katkop (Dairy)	21	8	99	AF85942	AD/NB		
Lowlands Estate	21	8	99	AF85942*	AD/NB	1.3	0
Katkop (Dairy)	21	8	99	AF85995	AD/NB		
Lowlands Estate	21	8	99	AF85995*	AD/NB	1.3	0
Riverside	30	6	97	AE08791	AD/NB		
Riverside	13	5	99	AE08791*	AD/NB	0	682
Riverside	30	6	97	AE08833	AD/NB		
Riverside	21	9	98	AE08833*	AD/NB	0	448
Riverside	30	6	97	AE08844	AD/NB		
Riverside	30	10	98	AE08844*	AD/M	0	487
Riverside	6	11	96	AE65130	AD/M		
Riverside	30	6	97	AE65130*	AD/NB	0	236
Riverside	17	7	97	AE65185	AD/NB		
Riverside	27	9	97	AE65185*	AD/NB	0	72
Riverside	28	10	97	AF00038	AD/M		
Riverside	12	12	97	AF00038*	AD/M	0	45
Riverside	12	12	97	AF00312	AD/M		
Riverside	27	1	99	AF00312*	AD/M	0	411
Riverside	24	6	98	AF24251	AD/NB		
Riverside	24	6	99	AF24251*	AD/NB	0	365
Riverside	24	6	98	AF24259	AD/NB		

APPENDIX 3 continued

Capture locality	Date of capture/recapture			Ring number	Age/sex	Distance travelled (km)	Time elapsed (days)
	Day	Month	Year				
Riverside	30	10	98	AF24259*	AD/M	0	128
Riverside	21	9	98	AF24591	AD/NB		
Riverside	13	5	99	AF24591*	AD/NB	0	234
Riverside	29	10	98	AF24807	AD/M		
Riverside	13	5	99	AF24807*	AD/M	0	196
Riverside	23	9	98	AF37606	AD/NB		
Riverside	30	10	98	AF37606*	AD/M	0	37
Riverside	24	9	98	AF37701	AD/NB		
Riverside	30	10	98	AF37701*	AD/M	0	36
Riverside	30	10	98	AF37832	AD/M		
Jacobsdal	10	11	99	AF37832*	AD	465	376
Riverside (chicks)	13	4	99	AF50261	J		
Riverside	23	6	99	AF50261*	NB	± 1	71
Riverside (chicks)	13	4	99	AF50305	AD/M		
Riverside	12	5	99	AF50305*	AD/M	± 1	29
Riverside	10	5	99	AF50342	AD/F		
Riverside	11	5	99	AF50342*	AD/F	0	1
Riverside	10	5	99	AF50377	J		
Riverside	11	5	99	AF50377*	J	0	1
Riverside	10	5	99	AF50381	J		
Riverside	12	5	99	AF50381*	J	0	2
Riverside	11	5	99	AF50423	AD/NB		
Riverside	13	5	99	AF50423*	AD/NB	0	2
Riverside	22	6	99	AF75219	J		
Riverside	23	6	99	AF75219*	J	0	1

APPENDIX 4

Estimated numbers of potential pest species observed at the Brandeston ostrich feedlot each month.

Date	Species				
	Sparrows (Cape & Grey-headed)	Weavers (Masked & Spotted-backed)	Quelea	Laughing Dove	Red-eyed Dove
Jul 97	99	13	97	127	18
Aug 97	89	268	62	150	50
Sep 97	36	47	7	153	8
Oct 97	97	8	138	78	42
Nov 97	69	19	0	97	7
Dec 97	72	160	0	147	13
Jan 98	67	40	0	102	0
Feb 98	94	105	3	186	15
Mar 98	114	0	0	91	27
Apr 98	242	7	4	140	17
May 98	248	116	232	96	22
Jun 98	269	29	1	37	5
Jul 98	178	113	2	56	5
Aug 98	248	38	3	52	4
Sep 98	127	18	20	58	11
Oct 98	108	20	5	33	12
Nov 98	86	2	0	41	8
Dec 98	45	4	11	60	10
Jan 99	67	0	5	14	10
Feb 99	33	14	1	21	1
Mar 99	128	7	1	29	1
Apr 99	112	2	25	34	6
May 99	93	10	100	24	5
Jun 99	135	17	0	11	3

APPENDIX 5

Estimated numbers of potential pest species observed at the Riverside Farm ostrich feedlot each month. Blank cells indicate months in which no data were collected.

Date	Species				
	Quelea	Rock Pigeon	Laughing Dove	Wattled Starling	Pied Starling
Jul 97	2690	219	83	844	18
Aug 97					
Sep 97	2515	72	71	498	69
Oct 97	736	140	366	4	43
Nov 97	2475	53	289	0	34
Dec 97	2390	40	220	32	21
Jan 98	70	267	324	0	3
Feb 98	351	581	247	0	43
Mar 98	876	500	236	0	72
Apr 98	2035	140	217	33	50
May 98	2652	14	217	211	14
Jun 98	8590	45	91	1561	79
Jul 98	7153	10	65	205	63
Aug 98	4455	10	141	340	94
Sep 98	9148	89	290	1491	181
Oct 98	5321	120	196	63	133
Nov 98	1938	150	143	0	58
Dec 98	6541	78	125	0	88
Jan 99	2428	18	374	15	51
Feb 99	322	0	176	18	21
Mar 99	146	6	224	0	19
Apr 99	1931	10	147	97	133
May 99	2580	8	396	291	115
Jun 99	12651	3	150	150	49

APPENDIX 6

Estimated numbers of potential pest species observed at the Katkop ostrich feedlot each month. Blank cells indicate months in which no data were collected.

Date	Species				
	Quelea	Laughing Dove	Rock Pigeon	Wattled Starling	Pied Starling
Jul 97	216	45	0	1	20
Aug 97					
Sep 97	241	40	0	0	22
Oct 97	283	133	0	0	4
Nov 97	1078	155	3	0	23
Dec 97					
Jan 98	986	175	3	0	1
Feb 98	338	104	2	0	0
Mar 98	50	15	11	0	0
Apr 98	57	14	0	0	4
May 98	112	11	0	0	29
Jun 98	31	33	0	0	16
Jul 98	90	20	0	2	5
Aug 98	7	14	0	0	0
Sep 98	10	42	0	0	11
Oct 98	102	108	3	15	3
Nov 98	10	309	5	0	1
Dec 98	2	180	12	0	12
Jan 99	0	7	0	0	0
Feb 99	3	4	0	0	13
Mar 99	1	8	0	0	1
Apr 99	0	24	0	9	5
May 99	50	8	0	15	5
Jun 99	0	2	0	1	2

APPENDIX 7

Analysis of the non-maize seed component of the diets of quelea and Laughing Doves at the Brandeston (B), Riverside Farm (R) and Katkop/Lowlands Estate (K) feedlots (1997 – 1999).

Species	Red-billed Quelea			Laughing Dove			Red-billed Quelea			Laughing Dove		
Farm	B	R	K	B	R	K	B	R	K		R	K
n	24	320	283	41	102	80	24	320	283	41	102	80
Seed Type	Percentage of birds that ate each seed type						Percentage of total mass of grass and weed seed comprised by each seed type					
Amaranthus & *Chenopodium* spp.	16.7	9.1	12.7	87.8	64.7	70.0	2.3	2.0	2.9	65.6	52.1	75.3
2		0.6	8.8			1.3		0.9	15.6			0.03
Urochloa panicoides	25.0	13.4	21.6	4.9	25.5	18.8	18.8	22.8	23.1	0.1	1.3	5.5
Digitaria sp.		1.3	5.3		1.0			0.3	3.4		0.02	
5					1.0						0.02	
6				12.2	5.9					5.5	0.4	
7			3.9			1.3			2.2			0.1
Atriplex semibaccata		0.3		4.9	3.9	11.3		0.2		0.1	0.1	1.1
9				4.9	2.0	1.3				0.9	1.0	0.1
Rhus sp.				2.4	9.8	1.3				0.03	1.8	0.03
11				4.9	8.8	3.8				0.1	0.3	0.2
12		0.3			3.9	3.8		0.1			0.2	0.4
13					6.9	6.3					2.0	0.2
14				2.4	2.9	1.3				0.1	0.1	0.2
17					6.9						0.3	
Sporobolus sp.?	16.7	0.9	3.5		1.0		16.7	0.2	0.7		0.02	
21	25.1		1.1				27.0		0.4			
22	33.4	0.9	1.1				4.5	0.2	0.1			
24	4.2					1.3	0.5					0.03
26	20.8		6.4			1.3	15.8		1.5			0.1
28		0.6		31.7	11.8	3.8		0.1		9.0	0.6	0.1
29					2.0						0.1	
Cereus jamacaru				12.2						1.6		
Rumex crispus		0.3	7.8	2.4	8.8	25.0		0.1	1.5	0.7	7.4	0.7
32		0.9	5.3					0.2	1.9			
33			0.4		1.0				0.1		0.04	
Echinochloa spp.	33.4	14.1	12.4	14.6	14.7	13.8	10.0	32.3	13.1	0.3	2.0	5.3
Solanum sp.		0.6	0.4	14.6	11.8	11.3		0.1	0.04	0.7	0.4	1.0
38				2.4						0.03		
40		0.3		4.9	1.0			0.1		0.2	0.04	
42			0.7						0.1			

APPENDIX 7 continued

Species	Red-billed Quelea			Laughing Dove			Red-billed Quelea			Laughing Dove		
Farm	B	R	K	B	R	K	B	R	K	B	R	K
n	24	320	283	41	102	80	24	320	283	41	102	80
Seed Type	Percentage of birds that ate each seed type						Percentage of total mass of grass and weed seed comprised by each seed type					
45		3.1	1.8	4.9	5.9	2.5		3.2	0.8	0.1	0.1	0.1
48			1.1			1.3			0.2			0.3
55			0.4						0.4			
62						1.3						0.03
63					2.0						0.1	
64			0.4	2.4		2.5			0.04	0.03		0.1
65				4.9	1.0	1.3				0.3	0.02	0.03
68				2.4	2.0					0.03	0.1	
76	4.2			2.4			0.5			0.03		
77				2.4	1.0	1.3				0.03	0.04	0.1
79	4.2	3.1	0.4	2.4	5.9		0.5	2.0	0.04	0.03	0.1	
86					1.0						0.02	
87						2.5						0.9
Panicum sp.		7.8	13.4		3.9	10.0		18.2	31.1		1.1	0.3
89				2.4						0.03		
90				2.4						0.03		
102		0.6			1.0			0.2			0.02	
Acacia karroo				7.3	2.9	2.5				13.8	0.4	2.1
109				2.4						0.1		
110		0.3						0.1				
112			0.4						0.04			
116	4.2	0.3	1.4				1.4	0.1	0.7			
117				2.4						0.03		
119	4.2						1.8					
120	4.2		0.4				0.5		0.1			
123		0.3	0.4					0.2	0.04			
127			0.4						0.04			
132					1.0						0.02	
135					1.0						0.04	
137					1.0						0.04	
139					2.9						1.6	
141						1.3						0.1
142					1.0	3.8					0.02	3.8
143						3.8						0.3
144						1.3						0.1

APPENDIX 7 continued

Species	Red-billed Quelea			Laughing Dove			Red-billed Quelea			Laughing Dove		
Farm	B	R	K	B	R	K	B	R	K	B	R	K
n	24	320	283	41	102	80	24	320	283	41	102	80
Seed Type	Percentage of birds that ate each seed type						Percentage of total mass of grass and weed seed comprised by each seed type					
146						2.5						0.9
147						3.8						0.4
148						1.3						0.03
151						2.5						0.1
152						1.3						0.1
153						1.3						0.03
154					1.0						0.07	
155						1.3						0.7
156					1.0						0.1	
157					1.0						0.04	
159					1.0						0.04	
161		0.3						0.1				
162		0.3						0.1				
164					1.0						0.04	
165					1.0						0.4	
166						1.3						0.6
167						1.3						0.03
Triticum sp. (Wheat)		2.2	0.4		11.8	2.5		16.7	0.1		24.2	0.2
Bean				2.4	1.0					0.8	1.3	
Tribulus terrestris					3.9						0.2	

APPENDIX 8

Seasonal changes in the diet of quelea captured at Riverside Farm between spring 1996 and winter 1999. Values are given as percentages with standard deviation. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug). No data were collected in summer 1996-1997 and autumn 1997.

Season (year)	n	Maize	Seeds	Unidentified plant matter	Animal matter
Spring (1996)	12	91.0 ± 25.5	8.4 ± 25.6	0.5 ± 0.2	0.1 ± 0.5
Winter (1997)	34	88.7 ± 26.8	10.0 ± 25.9	0	1.3 ± 5.7
Spring (1997)	33	89.7 ± 24.0	0.6 ± 1.9	4.9 ± 16.9	4.8 ± 10.8
Summer (1997-1998)	6	72.7 ± 33.7	17.9 ± 32.2	0	9.4 ± 10.1
Autumn (1998)	17	61.7 ± 43.6	26.3 ± 41.1	4.2 ± 9.5	7.8 ± 9.5
Winter (1998)	31	87.8 ± 25.5	6.9 ± 18.5	3.2 ± 17.7	2.1 ± 8.9
Spring (1998)	44	91.1 ± 25.1	7.2 ± 23.5	0	1.7 ± 4.8
Summer (1998-1999)	75	68.5 ± 40.7	29.1 ± 38.7	0.03 ± 0.2	2.3 ± 6.3
Autumn (1999)	50	79.5 ± 38.0	19.0 ± 36.2	0	1.5 ± 7.5
Winter (1999)	18	93.1 ± 22.7	5.7 ± 18.1	1.1 ± 4.7	0.1 ± 0.4

APPENDIX 9

Seasonal changes in the diet of quelea captured at feedlots in the Fish River area between winter 1997 and winter 1999. Values are given as percentages with standard deviation. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug).

Season (year)	n	Maize	Seeds	Unidentified plant matter	Animal matter
Winter (1997)	31	66.7 ± 38.0	23.2 ± 31.8	7.7 ± 24.5	2.5 ± 8.1
Spring (1997)	18	69.2 ± 41.0	14.5 ± 29.1	15.9 ± 31.2	0.3 ± 0.7
Summer (1997-1998)	21	46.2 ± 39.7	44.4 ± 37.5	6.0 ± 15.8	3.5 ± 7.9
Autumn (1998)	8	38.0 ± 43.4	40.8 ± 49.7	21.2 ± 34.8	0
Winter (1998)	35	79.2 ± 35.0	20.7 ± 34.5	0	0
Spring (1998)	55	98.6 ± 5.6	1.0 ± 5.4	0.1 ± 0.4	0.3 ± 0.7
Summer (1998-1999)	76	56.3 ± 45.2	33.6 ± 41.8	1.5 ± 11.5	8.7 ± 22.7
Autumn (1999)	20	51.6 ± 45.0	47.2 ± 45.6	1.1 ± 5.9	0.2 ± 0.6
Winter (1999)	19	54.2 ± 44.3	45.6 ± 44.3	0	0.2 ± 0.7

APPENDIX 10

Seasonal changes in the diet of Laughing Doves captured at Riverside Farm between winter 1997 and winter 1999. Values are given as percentages with standard deviation. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug).

Season (year)	n	Maize	Seeds	Unidentified plant matter	Animal matter
Winter (1997)	3	98.6 ± 1.2	1.4 ± 1.2	0	0
Spring (1997)	15	68.7 ± 38.3	11.3 ± 15.5	20.0 ± 29.1	0.05 ± 0.1
Summer (1997-1998)	7	81.4 ± 34.3	15.2 ± 34.6	3.4 ± 8.3	0
Autumn (1998)	12	58.9 ± 37.8	38.9 ± 36.0	2.2 ± 4.6	0
Winter (1998)	6	87.9 ± 14.0	10.6 ± 11.0	1.5 ± 3.7	0
Spring (1998)	18	77.4 ± 27.6	22.2 ± 27.6	0	0.4 ± 0.7
Summer (1998-1999)	19	49.3 ± 44.1	45.5 ± 43.8	5.2 ± 21.8	0.05 ± 0.1
Autumn (1999)	16	74.3 ± 25.3	22.7 ± 25.5	2.9 ± 8.4	0.06 ± 0.2
Winter (1999)	6	79.2 ± 30.2	20.8 ± 30.2	0	0.02 ± 0.04

APPENDIX 11

Seasonal changes in the diet of Laughing Doves captured at feedlots in the Fish River area between winter 1997 and winter 1999. Values are given as percentages with standard deviation. Spring (Sep-Nov); Summer (Dec-Mar); Autumn (Apr-May); Winter (Jun-Aug).

Season (year)	n	Maize	Seeds	Unidentified plant matter	Animal matter
Winter (1997)	4	45.7 ± 46.1	10.6 ± 6.4	43.8 ± 43.8	0
Spring (1997)	7	32.7 ± 42.8	21.9 ± 27.1	45.4 ± 40.3	0
Summer (1997-1998)	14	54.4 ± 42.7	21.8 ± 32.9	23.7 ± 35.1	0.06 ± 0.2
Autumn (1998)	5	22.3 ± 39.0	40.1 ± 46.8	37.2 ± 44.5	0.4 ± 0.9
Winter (1998)	8	54.7 ± 30.2	30.3 ± 24.9	15.0 ± 32.7	0.04 ± 0.1
Spring (1998)	7	85.9 ± 17.3	11.7 ± 12.6	0.5 ± 1.3	1.8 ± 3.8
Summer (1998-1999)	25	71.6 ± 35.9	17.7 ± 28.7	9.2 ± 23.3	1.5 ± 5.2
Autumn (1999)	7	77.0 ± 33.8	22.8 ± 33.8	0.03 ± 0.07	0.2 ± 0.3
Winter (1999)	3	99.6 ± 0.5	0.3 ± 0.2	0	0.2 ± 0.3

APPENDIX 12

Summary of management options for reducing loss of crushed maize to problem birds at Eastern Cape feedlots.

Management technique	Advantages	Disadvantages	Recommended use
Alpha-chloralose	Relatively easy to prepare and lay bait. Only affects birds causing damage. Potential for non-target species to be revived and released.	Poor response to pre-baiting in the presence of alternative feeding sites. High risk of secondary poisoning through dispersal of affected birds from bait site. Not yet registered for use in South Africa. Considerable local movement and rapid immigration make any form of lethal control inappropriate.	At best a temporary solution, but if timed correctly may help limit damage to ripening crops through short-term reduction of local bird numbers.
Orange pulp	Cheap (< 2c per bird per day) and easy to mix into existing ration. May increase nutritional value of ration. Natural product therefore exempt from expensive registration procedures.	Only effective when alternative food sources are available.	Most useful in summer and autumn when natural seeds are abundant.
Whole maize	Cheaper than crushed maize. Cannot be eaten by small granivorous birds. Effective in the absence of alternative food sources.	Whole kernels tend to be selected by dominant ostriches and this affects the composition of the ration. Can still be utilised by doves, pigeons and possibly starlings.	Suitable for use throughout the year. If timed correctly may cause sufficient local food shortage in winter to force quelea to leave the area. Should be alternated with periods when crushed maize is fed so that growth of ostriches is not affected.

REFERENCES

ACOCKS, J.P.H. 1975. Veld types of South Africa. *Memoirs of the Botanical Survey of South Africa.* **40**: 1-128.

ALLAN, R. 1996. *The grain-eating birds of Sub-Saharan Africa: Identification, biology and management.* Chatham: Natural Resources Institute.

AUBIN, T. 1990. Synthetic bird calls and their application to scaring methods. *Ibis.* **132**: 290-299.

AVERY, M.L. 1995. Recent research on controlling bird damage to blueberries. *Proceedings of the 7th Biennial Southeast Blueberry Conference and Trade Show*: 73-78.

AVERY, M.L. & MATTESON, R.E. 1995. Effectiveness of dimethyl anthranilate and eyespots for reducing feed consumption by starlings. *Proceedings of the 6th Eastern Wildlife Damage Control Conference:* 128-133.

BECKER, P. & AMIR, O.S. 1993. Effects on non-target birds through spraying operations on Quelea roost and colonies in Somalia. *Lanioturdus.* **27**: 58-63.

BELANT, J.L & SEAMANS, T.W. 1997. Comparison of three formulations of alpha-chloralose for immobilization of Canada Geese. *Journal of Wildlife Diseases.* **33**: 606-610.

BERGMAN, D.L., PUGH, T.L., HUFFMAN, L.E. 1997. Nonlethal control techniques used to manage blackbird damage to sunflower. In: LEE, C.D. & HYGNSTROM, S.E. (Eds), *Proceedings of the 13th Great Plains Wildlife Damage Control Workshop*: 81-87.

BERRUTI, A. 1995. An investigation into the biology of the Redbilled Quelea *Quelea quelea* in the Bergville-Winterton area of KwaZulu-Natal. Final Report to the Directorate: Resource Conservation of the Department of Agriculture of the Republic of South Africa.

BERRUTI, A. 2000. The pest status and biology of the Red-billed Quelea in the Bergville-Winterton area of South Africa. In: CHEKE, R.A., ROSENBERG, L.J. & KEISER, M.E. (Eds), *Workshop on research priorities for migrant pests of agriculture in southern Africa.* Chatham: Natural Resources Institute: 113-118.

BESSER, J.F., DE GRAZIO, J.W. & GUARINO, J.L. 1968. Costs of wintering starlings and Red-winged Blackbirds at feedlots. *Journal of Wildlife Management.* **32**: 179-180.

BEZUIDENHOUT, A.G. 1995. Praktiese bestuursriglyne vir volstruise (Inleiding). *Döhne Bulletin.* **4**: 1-3.

BOGATICH, V. 1967. The use of live traps to remove starlings and protect agricultural products in the state of Washington. *Proceedings of the 3rd Vertebrate Pest Conference:* 98-99.

BOMFORD, M. & O'BRIEN, P.H. 1990. Sonic deterrents in animal damage control: A review of device tests and effectiveness. *Wildlife Society Bulletin.* **18**: 411-422.

BORG, K. 1955. Om chloralosen och dess användning vid fångst av kråk-och måsfåglar, duvor etc. (English summary). *Viltrevy Jakt - biologist Tidskrift.* **1**: 88-121.

BOUDREAU, G.W. 1968. Alarm sounds and responses of birds and their application in controlling problem species. *The Living Bird.* **7**: 27-46.

BRADFIELD, R.D. 1932. Unusual experiences with birds. *Ostrich.* **3**: 13-16.

BRANDT, H.D. & MALHERBE, A. 1967. A revised list of the birds of Potchefstroom. *South African Avifauna Series.* **51**: 1- 32.

BROODRYK, S. 1998. The present situation (of the ostrich industry) and future view. *Newsletter of the East Cape Ostrich Producers Association March / April.* 6-7.

BROOKE, R.K. 1985. Range expansion in the Cape Province, and the problem of the type locality of the Masked Weaver *Ploceus velatus* Vieillot. *Ostrich.* **56**: 214-215.

BROOKS, J.E. & HUSSAIN, I. 1990. Chemicals for bird control. In: BROOKS, J.E., AHMAD, E., HUSSAIN, I., MUNIR, S. & KHAN, A.A. (Eds), *Vertebrate Pest Management, a Training Manual.* Islamabad: Pakistan Agricultural Research Council: 193-195.

BROWN, R.G.B. 1969. Seed selection by pigeons. *Behaviour.* **34**: 115-131.

BRUGGERS, R.L. 1989. Uses of radio-telemetry in quelea management. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 61-65.

BRUGGERS, R.L. RODRIGUEZ, E. & ZACCAGNINI, M.E. 1998. Planning for bird pest problem resolution: A case study. *International Biodeterioration and Biodegradation.* **42**: 173-184.

BRUGGERS, R.L. & ZACCAGNINI, M.E. 1994. Vertebrate pest problems related to agricultural production and applied research in Argentina. *Vida Silvestre Neotropical.* **3**: 71-83.

BRUNET, R., CAZA, N. & CYR, A. 1996. Food intake and circadian rhythms of activity of Red-winged Blackbirds (*Agelaius phoeniceus*). A time-course study of the effects of alpha-chloralose and secobarbital. *Biological Rhythm Research.* **27**: 227-240.

BUCHER, E.H. 1990. The influence of changes in regional land-use patterns on *Zenaida* Dove populations. In: PINOWSKI, J. & SUMMERS-SMITH, J.D. (Eds), *Granivorous birds in the agricultural landscape.* Warszawa: Polish Scientific Publishers: 291-303.

BUCHER, E.H. & BEDANO, P.E. 1976. Bird damage problems in Argentina. *International studies on sparrows.* **9**: 3-18.

BULLARD, R.W. & GEBREKIDAN, B. 1989. Agronomic techniques to reduce quelea damage to cereals. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's Bird Pest.* Oxford: Oxford University Press: 281-292.

CABE, P.R. 1993. European Starling *Sturnus vulgaris.* In: POOLE, A. & GILL, T. (Eds), *The Birds of North America, No 48.* Washington, DC: The American Ornithologists' Union and The Academy of Natural Sciences of Philadelphia: 1-23.

CAITHNESS, T.A. 1968. Poisoning gulls with alpha-chloralose near a New Zealand airfield. *Journal of Wildlife Management.* **32**: 279-286.

CARYER, Z. 1996. 1996 Southern African regional congress of the International Meat Secretariat (IMS). *Newsletter of the East Cape Ostrich Producers Association September / October.* 8-13.

CHAN, K. & KIKKAWA, J. 1997. A Silvereye dilemma: To migrate or not to migrate? *Emu.* **97**: 91-93.

CLANCEY, P.A. 1960. A new race of Red-billed Quelea from south-eastern Africa. *Bulletin of the British Ornithologists' Club.* **80**: 67-68.

CLANCEY, P.A. 1973. Miscellaneous taxonomic notes on African birds, 37. The subspecies of the *lathamii*-group of *Quelea quelea* (Linnaeus). *Durban Museum Novitates.* **10**: 13-22.

CLARK, J.P. & HYGNSTROM, S.E. 1994. House Finches (Linnets). In: HYGNSTROM, S.E., TIMM, R.M. & LARSON, G.E. (Eds), *Prevention and control of Wildlife damage.* Lincoln: University of Nebraska Cooperative Extension Division: E67-E70.

COLAHAN, B.D. 1997. Rock Pigeon *Columba guinea.* In: HARRISON, J.A., ALLAN, D.G., UNDERHILL, L.G., HERREMANS, M., TREE, A.J., PARKER, V. & BROWN, C.J. (Eds), *The atlas of southern African birds.* Vol. 1: Non-Passerines. Johannesburg: BirdLife South Africa: 502-503.

COLAHAN, B.D. & HARRISON, J.A. 1997. Laughing Dove *Streptopelia senegalensis.* In: HARRISON, J.A., ALLAN, D.G., UNDERHILL, L.G., HERREMANS, M., TREE, A.J., PARKER, V. & BROWN, C.J. (Eds), *The atlas of southern African birds.* Vol. 1: Non-Passerines. Johannesburg: BirdLife South Africa: 512-513.

COLLETT, J. 1982. Birds of the Cradock District. *Southern Birds.* **9**: 1-65.

CONOVER, M.R. 1984. Comparative effectiveness of avitrol, exploders, and hawk-kites in reducing blackbird damage to corn. *Journal of Wildlife Management.* **48**: 109-116.

CONOVER, M.R. & DOLBEER, R.A. 1989. Reflecting tapes fail to reduce blackbird damage to ripening cornfields. *Wildlife Society Bulletin.* **17**: 441-443.

COOKE, C.K. & COOKE, P. 1969. List of birds of the Qolora River Mouth area. *South African Avifauna Series.* **63**: 1-9.

CORNWELL, P.B. 1966. Control of House Sparrows with alphachloralose. *International Pest Control.* **8**: 10-13.

COURTENAY-LATIMER, M. 1964. Check list of the birds of the East London area. *South African Avifauna Series.* **20**: 1-76.

CRAIG, A.J.F.K. 1983. Moult in southern African passerine birds: A review. *Ostrich.* **54**: 220-237.

CRAIG, A.J.F.K. 1989a. The social behaviour of the Red-billed Quelea. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), Africa's *Feathered Locust.* Harare: Baobab Books: 18-23.

CRAIG, A.J.F.K. 1989b. Pied Starling *Spreo bicolor.* In: GINN, P.J., McILLERON, W.G. & MILSTEIN, P. le S. (Eds), *The complete book of southern African birds.* Cape Town: Struik Winchester: 613.

CRAIG, A.J.F.K. & HULLEY, P.E. 1994. Sunbird movements: A review, with possible models. *Ostrich.* **65**: 106-110.

CRAIG, A.J.F.K. & MANSON, A.J. 1979. Moult of the Red Bishop and related species of *Euplectes. Ostrich.* **50**: 65-69.

CRAIG, A.J.F.K., HULLEY, P.E., WHITTINGTON-JONES, C.A. & BONNEVIE, B. 2001. Flying times and flight feathers: patterns of moult in sympatric seedeaters. *Ostrich supplement.* **15**: 66-70.

CROCKER, D.R. & PERRY, S.M. 1990. Plant chemistry and bird repellents. *Ibis.* **132**: 300-308.

CYR, J. 1977. Experiments with alpha-chloralose to control harmful birds. *Bird-Banding.* **48**: 125-137.

CYR, A. & BRUNET, R. 1992. Anesthetization of captive Red-winged Blackbirds with mixtures of alpha-chloralose and secobarbital. *Journal of Wildlife Management.* **56**: 806-809.

DAVIES, C.G. 1907. Notes on birds observed and collected in the districts of Port St. Johns, Lusikisiki, Flagstaff, and Bizana, Pondoland, during the years 1904-1906 and the beginning of 1907. *Journal of the South African Ornithologists' Union.* **3**: 180-206.

DAVIES, C.G. 1910. A second contribution to the ornithology of Eastern Pondoland. *Journal of the South African Ornithologists' Union.* **6**: 5-14.

DAWSON, D.G. 1970. Estimation of grain loss due to sparrows (*Passer domesticus*) in New Zealand. *New Zealand Journal of Agricultural Research.* **13**: 681-688.

DE GRAZIO, J.W. 1989. Pest birds - an international perspective. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 1-8.

DE KLERK, W. de K. 1942. Notes on nests of birds in Adelaide, C.P. *Ostrich.* **13**: 57-63.

DEAN, W.R.J. 1979. Population, diet and the annual cycle of the Laughing Dove at Barberspan, Part 2: Diet. *Ostrich.* **50**: 215-219.

DEAN, W.R.J. 1989. Wattled Starling *Creatophora cinerea.* In: GINN, P.J., McILLERON, W.G. & MILSTEIN, P. le S. (Eds), *The complete book of southern African birds.* Cape Town: Struik Winchester: 614.

DE BEER, S.J., LOCKWOOD, G.M., RAIJMAKERS, J.H.F.A., RAIJMAKERS, J.M.H., SCOTT, W.A., OSCHADLEUS, H.D. & UNDERHILL, L.G. (Eds). 2000. SAFRING Bird Ringing Manual. *ADU Guide.* **5**: 1-102.

DOLBEER, R.A. 1986. Current status and potential of lethal means of reducing bird damage in agriculture. *Proceedings of the 19th International Ornithological Conference*: 474-483.

DOLBEER, R.A. 1990. Ornithology and integrated pest management: Red-winged Blackbirds *Agelaius phoeniceus* and corn. *Ibis.* **132**: 309-322.

DOLBEER, R.A. 1997. Controlling bird damage in vineyards and other fruit crops. *Proceedings of the Ohio Grape-wine Short Course.* **667**: 92-95.

DOLBEER, R.A., HOLLER, N.R. & HAWTHORNE, D.W. 1994. Identification and control of Wildlife Damage. In: BOOKHOUT, T.A. (Ed.), *Research and Management Techniques for Wildlife and Habitats.* Bethesda, Maryland: The Wildlife Society: 474-506.

EARLÉ, R.A. 1988. Reproductive isolation between urban and rural populations of Cape Sparrows and House Sparrows. *Acta XIX Congressus Internationalis Ornithologici.* **2**: 1778-1786.

ELLIOTT, C.C.H. 1979. The harvest time method as a means of avoiding quelea damage to irrigated rice in Chad/Cameroun. *Journal of Applied Ecology.* **16**: 23-35.

ELLIOTT, C.C.H. 1989a. The pest status of the quelea. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 17-34.

ELLIOTT, C.C.H. 1989b. The quelea as a major problem in a food-deficient continent. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds). *Africa's Feathered Locust*. Harare: Baobab Books: 90-99.

ELLIOTT, C.C.H. 1990. The migrations of the Red-billed Quelea *Quelea quelea* and their relation to crop damage. *Ibis*. **132**: 232-237.

ELLIOTT, C.C.H. 1998. I.O.C. round table on the quelea. *Safring News*. **27**: 35-36.

ELLIOTT, C.C.H. & LENTON, G.M. 1989. Monitoring the quelea. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest*. Oxford: Oxford University Press: 35-49.

ERICKSON, W.A. 1989. Feeding ecology of quelea. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's Bird Pest*. Oxford: Oxford University Press: 230-247.

FAZLUL HAQUE, A.K.M. & BROOM, D.M. 1985. Experiments comparing the use of kites and gas bangers to protect crops from Woodpigeon damage. *Agriculture, Ecosystems and Environment*. **12**: 219-228.

FEARE, C.J. 1974. Ecological studies of the Rook (*Corvus frugilegus*) in north-east Scotland. Damage and its control. *Journal of Applied Ecology*. **11**: 897-914.

FEARE, C.J. 1975. Cost of starling damage at an intensive animal husbandry unit. *Proceedings of the 8th British Insecticide and Fungicide Conference*: 253-259.

FEARE, C.J. 1980. The economics of starling damage. In: WRIGHT, E.N., INGLIS, I.R. & FEARE, C.J. (Eds), Bird *problems in agriculture*. Croydon: BCPC Publications: 39-55.

FEARE, C.J. 1984. *The Starling*. Oxford, UK: Oxford University Press.

FEARE, C.J. 1989. The changing fortunes of an agricultural bird pest: The European Starling. *Agricultural Zoology Reviews*. **3**: 317-342.

FEARE, C.J. 1990. Local movements of starlings in winter. *Acta XVII International Ornithological Congress*. **2**: 1331-1336.

FEARE, C.J. 1994. Changes in numbers of Common Starlings and farming practice in Lincolnshire. *British Birds*. **87**: 200-204.

FEARE, C.J. & CRAIG, A.J.F.K. 1998. *Starlings and mynas*. London: Christopher Helm.

FEARE, C.J., GREIG-SMITH, P.W. & INGLIS, I.R. 1986. Current status and potential of non-lethal means of reducing bird damage in agriculture. *Proceedings of the 19th International Ornithological Congress:* 493-506.

FEARE, C.J., ISAACSON, A.J., SHEPPARD, P.A. & HOGAN, J.M. 1981. Attempts to reduce starling damage at dairy farms. *Protection Ecology.* **3**: 173-181.

FEARE, C.J. & SWANNACK, K.P. 1978. Starling damage and its prevention at an open-fronted calf yard. *Animal Production.* **26**: 259-265.

FEARE, C.J. & WADSWORTH, J.T. 1981. Starling damage on farms using the complete diet system of feeding dairy cows. *Animal Production.* **32**: 179-183.

FFRENCH, R.P. 1967. The Dickcissel on its wintering grounds in Trinidad. *The Living Bird.* **6**: 123-140.

FIEDLER, L.A., FALL, M.W., BRUGGERS, R.L. & DE GRAZIO, W. 1991. Rodent and bird problems in agriculture and their management in developing countries. *Proceedings of the 11th International Congress of Plant Protection.* **1**: 65-73.

FITZWATER, W.D. 1994. House Sparrows. In: HYGNSTROM, S.E., TIMM, R.M. & LARSON, G.E. (Eds), *Prevention and control of Wildlife damage.* Lincoln: University of Nebraska Cooperative Extension Division: E101-E108.

FOLK, Č. & KOŽENÁ, I. 1982. Winter food resource partitioning among three granivorous bird species in agricultural farms. *Folia Zoologica.* **31**: 127-137.

FRETWELL, S. 1986. Distribution and abundance of the Dickcissel. In: JOHNSTON, R.F. (Ed.), *Current Ornithology.* **4**: New York: Plenum Press: 211-242.

GADD, P., Jr. 1996. Use of the modified Australian crow trap for the control of depredating birds in Sonoma County. *Proceedings of the 17th Vertebrate Pest Conference*: 103-107.

GATES, D.M. 1993. *Climate change and its biological consequences.* Sunderland, Massachusetts: Sinauer Associates, Inc.

GEERTSEMA, L. 1998. Redbilled Quelea Annual Report. Directorate Agricultural Resource Conservation of the National Department of Agriculture, Pretoria.

GICHUKI, N.N. 1984. The pest status of some granivorous birds in the eastern Machakos District, Kenya. *Proceedings of the 5th Pan-African Ornithological Congress*: 371-386.

GILL, L. 1936. *A first guide to South African birds.* Cape Town: Maskew Miller.

GILL, L. 1970. *A first guide to South African birds.* (Revised by WINTERBOTTOM, J.M.). Cape Town: Maskew Miller.

GINN, H.G. & MELVILLE, D.S. 1983. *Moult in birds.* Tring: The British Trust for Ornithology.

GLAHN, J.F., MASON, J.R. & WOODS, D.R. 1989. Dimethyl anthranilate as a bird repellent in livestock feed. *Wildlife Society Bulletin.* **17**: 313-320.

GLAHN, J.F. & OTIS, D.L. 1986. Factors influencing blackbird and European Starling damage at livestock feeding operations. *Journal of Wildlife Management.* **50**: 15-19.

GLAHN, J.F., TIMBROOK, S.K. & TWEDT, D.J. 1987. Temporal use patterns of wintering starlings at a southeastern livestock farm: Implications for damage control. *Proceedings of the Eastern Wildlife Damage Control Conference.* **3**: 194-203.

GLAHN, J.F., TWEDT, D.J. & OTIS, D.L. 1983. Estimating feed loss from starling use of livestock feed troughs. *Wildlife Society Bulletin.* **11**: 366-372.

GODFREY, R. 1918. The birds of the Buffalo Basin, Cape Province. *South African Journal of Natural History.* **1**: 73-82.

GODFREY, R. 1925. Nesting of the Pinkbilled Quelea at Peuleni. *Blythswood Review.* **2**: 57.

GODFREY, R. 1932. Birds of the Eastern Cape Province. *Blythswood Review.* **9**: 96.

GODFREY, R. 1945. Birds of the Buffalo Basin C.P. *Ostrich.* **16**: 169-175.

GRAMET, P. & DUBAILLE, E. 1983. Modifications des aires d'hivernages des étourneaux sansonnets (*Sturnus vulgaris* L) dans les regions maritimes du nord de la Loire. *Bulletin de la Société des Sciences naturelles de l'Ouest de la France.* n.s. **5**: 163-172 .

GREGORY, N.G. & WILKINS, L.J. 1997. Stupefying and lethal effects of alphachloralose in chickens. *New Zealand Journal of Agricultural Research.* **40**: 361-364.

GTZ. 1987. The ecology and control of the Red-billed Weaver Bird (*Quelea quelea* L.) in northeast Nigeria. Special Publication Number 199: Eschborn, West Germany: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

HAAGNER, A.K. 1905. Ornithology of Modderfontein, Transvaal. *Journal of the South African Ornithologists' Union.* **1**: 50.

HAAGNER, A. & IVY, R.H. 1907. The birds of Albany Division, Cape Colony. *Journal of the South African Ornithologists' Union.* **3**: 76-116.

HAAGNER, A. & IVY, R.H. 1908. *Sketches of South African bird-life.* London: R.H. Porter.

HALL, T.C. 1994. Magpies. In: HYGNSTROM, S.E., TIMM, R.M. & LARSON, G.E. (Eds), Prevention *and control of Wildlife damage.* Lincoln, NE: University of Nebraska Cooperative Extension Division: E79-E85.

HEDENSTRÖM, A. 1998. The relationship between wing area and raggedness during molt in the Willow Warbler and other passerines. *Journal of Field Ornithology.* **69**: 103-108.

HEWITT, J. 1932. Notes from Cofimvaba. *Blythswood Review.* **9**: 29.

HURLEY, R.J. & FRANKS, E.C. 1976. Changes in the breeding ranges of two grassland birds. *Auk.* **93**: 108-115.

HUSSAIN, I. 1990. Trapping, netting and scaring techniques for bird control. In: BROOKS, J.E., AHMAD, E., HUSSAIN, I., MUNIR, S. & A.A. KHAN. (Eds), *Vertebrate Pest Management, a Training Manual.* Islamabad: Pakistan Agricultural Research Council: 187-191.

INGLIS, I.R., ISAACSON, A.J., THEARLE, R.J.P. & WESTWOOD, N.J. 1990. The effects of changing agricultural practice upon Woodpigeon *Columba palumbus* numbers. *Ibis.* **132**: 262-272.

IRWIN, M.S.P. 1989. The genus *Quelea*. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), *Africa's Feathered Locust.* Harare: Baobab Books: 9-13.

JACKSON, J.J. & ALLAN, R.G. 1989. Historical overview of quelea research and control. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 9-16.

JAEGER, M.M. 1992. Selective control in Quelea populations in Eastern Africa. In: McCULLOUGH, D.R. & BARRETT, R.H. (Eds.), *Wildlife 2001: Populations.* London: Elsevier. 313-320.

JAEGER, M.E. & ELLIOTT, C.C.H. 1989. Quelea as a resource. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 327-338.

JAEGER, M.M., ELLIOTT, C.C.H., BRUGGERS, R.L. & ALLAN, R.G. 1989. Distribution, populations, and migration patterns of quelea in eastern Africa. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest.* Oxford: Oxford University Press: 113-131.

JAMES, H.W. 1921. Notes on birds occurring in the Cradock and Tarkastad districts, Cape Province, with nesting dates. *South African Journal of Natural History.* **3**: 174-198.

JARVIS, M.J.F. 1983. Birds and man interactions in Zimbabwe. *Proceedings of the Symposium on Birds and Man*: 119-129.

JARVIS, M.J.F. 1989. Quelea breeding and seasonal distribution in southern Africa. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), Africa's *feathered locust.* Harare: Baobab Books: 69-83.

JARVIS, M.J.F. & VERNON, C.J. 1989a. Food and feeding habits of quelea in southern Africa. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), Africa's *Feathered Locust.* Harare: Baobab Books: 24-35.

JARVIS, M.J.F. & VERNON, C.J. 1989b. Notes on quelea breeding in southern Africa. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), Africa's *Feathered Locust*. Harare: Baobab Books: 50-68.

JOHNS, B.E., BRUGGERS, R.L. & JAEGER, M.M. 1989. Mass-marking quelea with fluorescent pigment particles. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest*. Oxford: Oxford University Press: 50-60.

JOHNSON, R.J. & GLAHN, J.F. 1994. European Starlings. In: HYGNSTROM, S.E., TIMM, R.M. & LARSON, G.E. (Eds), Prevention *and control of Wildlife damage*. Lincoln. University of Nebraska Cooperative Extension Division: E109-E120.

JOHNSTON, 1907. Destructive birds. *Journal of the South African Ornithologists' Union*. **3**: 135-136.

JONES, P.J. 1989a. General aspects of quelea migrations. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest*. Oxford: Oxford University Press: 102-112.

JONES, P.J. 1989b. Distribution, populations, and migration patterns of quelea in southern Africa. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest*. Oxford: Oxford University Press: 132-143.

JONES, P.J. 1989c. Factors determining the breeding season and clutch size. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), *Quelea quelea Africa's bird pest*. Oxford: Oxford University Press: 158-180.

JONES, P.J. 1989d. The breeding cycle of queleas and factors initiating breeding. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), Africa's *Feathered Locust*. Harare: Baobab Books: 36-49.

JONES, P.J., CHEKE, R.A., MUNDY, P.J., DALLIMER, M. & VENN, J.F. 2000. Quelea populations and forecasting in southern Africa. In: CHEKE, R.A., ROSENBERG, L.J. & KEISER, M.E. (Eds), *Workshop on research priorities for migrant pests of agriculture in southern Africa*. Chatham: Natural Resources Institute: 139-149.

JONES, P.J. DALLIMER, M., CHEKE, R.A. & MUNDY, P.J. in press. Are there two subspecies of Redbilled Quelea *Quelea quelea* in southern Africa? *Ostrich*.

KEARNS, G.D., KWARTIN, N.B., BRINKER, D.F. & HARAMIS, G.M. 1998. Digital playback and improved trap design enhances capture of migrant Soras and Virginia Rails. *Journal of Field Ornithology*. **69**: 466-473.

KEITH, J.O. & BRUGGERS, R.L. 1998. Review of hazards to raptors from pest control in Sahelian Africa. *Journal of Raptor Research*. **32**: 151-158.

KEITH, J.O., NGONDI, J.G., BRUGGERS, R.L. KIMBALL, B.A. & ELLIOTT, C.C.H. 1994. Environmental effects on wetlands of Queletox® applied to Ploceid roosts in Kenya. *Environmental Toxicology and Chemistry*. **13**: 333-341.

KESSEL, B. 1953. Distribution and migration of the European Starling in North America. *Condor.* **55**: 49-67.

KIESER, J.A. & KIESER, G.A. 1978. Birds of the De Aar district. *Southern Birds.* **5**: 1-46.

KING, J.R. 1980. Energetics of avian moult. *Acta XVII International Ornithological Congress.* **1**: 312-317.

KOK, O.B. & VAN EE, C.A. 1990. Dieetsamestelling van enkele voëlsoorte in die Oranje-Vrystaat en Noordwes-Kaap. 3. Lede van die Sturnidae-Familie. *Mirafra.* **7**: 18-25.

LANE, A.A. 1930. Some notes on weavers and widow-birds. *Ostrich.* **1**: 22-24.

LAZARUS, J. 1979. Flock size and behaviour in captive red-billed weaverbirds (*Quelea quelea*): Implications for social facilitation and the functions of flocking. *Behaviour.* 71: 127-145.

LINZ, G.M., LINZ, L.J., THOMPSON, J.M. & BLEIER, W.J. 1993a. Using geographic variation to predict breeding locales of migrating Red-winged Blackbirds. *Prairie Naturalist.* **25**: 127-133.

LINZ, G.M., DOLBEER, R.A., HANZEL, J.J. & HUFFMAN, L.E. 1993b. Controlling blackbird damage to sunflower and grain crops in the Northern Great Plains. *Agriculture Information Bulletin No. 679.* Washington, DC: USDA, Animal and Plant Health Inspection Service: 1-15.

LITTLE, R.M. 1994. Marked dietary differences between sympatric feral rock doves and rock pigeons. *South African Journal of Zoology.* **29**: 33-35.

LIVERSIDGE, R. 1943. Sacred Ibis at East London. *Ostrich.* **14**: 116-117.

LOIBL, M.F., CLUTTON, R.E., MARX, B.D. & McGRATH, C.J. 1988. Alpha-chloralose as a capture and restraint agent of birds: Therapeutic index determination in the chicken. *Journal of Wildlife Diseases.* **24**: 684-687.

LONG, J.L. 1962. Bird problems and control in Western Australia. *Journal of the Western Australia Department of Agriculture.* **3**: 502-505.

LONG, J.L. 1965. The Starling. *Journal of the Western Australia Department of Agriculture.* **6**: 144-147.

LONG, J.L. 1968. The Indian Mynah. *Journal of the Western Australia Department of Agriculture.* **9**: 376-377.

LONG, J.L. 1990. Parrots. In: LONG, J. (Co-ord. ed.), *Declared Animal Control Handbook:* Agricultural Protection Board: A6.1-5.

LONG, J.L., MAWSON, P.R. & LITTLEY, M. 1989. Evaluation of some scaring devices for preventing damage by parrots to cultivated fruit. *Agriculture Protection Board Technical Series*. **5**: 1-13.

LOURENS, D.C. 1961. Comments on the new race of the Red-billed Quelea. *Ostrich*. **32**: 187.

LOURENS, D.C. 1963. *The Red-billed Quelea. A contribution to the bio-ecology and control*. Unpublished D.Sc. Thesis, Department of Agriculture, Pretoria.

LUDICK, R.D. 1997. *Implications of seed preference for control of the Red Bishop at Eastern Cape cattle feedlots*. Unpublished B.Sc. Honours thesis, Rhodes University, Grahamstown, Republic of South Africa.

MACDONALD, I.A.W. 1986. Range expansion in the Pied Barbet and the spread of alien tree species in southern Africa. *Ostrich*. **57**: 75-94.

MACLEAN, G.L. 1993. Robert's birds of southern Africa. Cape Town: The trustees of the John Voelcker Bird Book Fund.

MANIKOWSKI, S. 1980. The dynamics of the Chari-Logone population of *Quelea quelea* and its control. *Proceedings of the 4th Pan-African Ornithological Congress*: 411-421.

MANYANZA, D.N. 1980. Energetics and mode of *Quelea quelea* migration in Tanzania. *East Afican Agricultural and Forestry Journal*. **46**: 38-44.

MARX, E. 1995. Erosion problems in ostrich farming. *Döhne Bulletin*. **4**: 4-6.

MASON, J.R. & CLARK, L. 1995. Evaluation of methyl anthranilate and activated charcoal as Snow Goose grazing deterrents. *Crop Protection*. **14**: 467-469.

MASON, J.R. & LINZ, G. 1997. Repellency of garlic extract to European Starlings. *Crop Protection*. **16**: 107-108.

MASON, J.R. & MATTHEW, D.N. 1996. Evaluation of neem as a bird repellent chemical. *International Journal of Pest Management*. **42**: 47-49.

MASSAM, M. 1990. Little Corella *Cacatua pastinator*. In: LONG, J. (Co-ord. ed.), *Declared Animal Control Handbook:* Agricultural Protection Board: A5.1-4.

McLENNAN, J.A., LANGHAM, N.P.E. & PORTER. R.E.R. 1995. Deterrent effect of eye-spot balls on birds. *New Zealand Journal of Crop and Horticultural Science*. **23**: 139-144.

MENDELSSOHN, H. & YOM-TOV, Y. 1999. A report of birds and mammals which have increased their distribution and abundance in Israel due to human activity. *Israel Journal of Zoology*. **45**: 35-47.

MILSOM, T.P. 1990. Lapwings *Vanellus vanellus* on aerodromes and the birdstrike hazard. *Ibis.* **132**: 218-231.

MOORCROFT, J. 1992. Recent reports. *Bee-eater.* **43**: 47.

MUNDY, P.J. 1989. Physical features of southern Africa. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), *Africa's feathered locust.* Harare: Baobab Books: 1-8.

MUNDY, P.J. & HERREMANS, M. 1997. Redbilled Quelea *Quelea quelea.* In: HARRISON, J.A., ALLAN, D.G., UNDERHILL, L.G., HERREMANS, M., TREE, A.J., PARKER, V. & BROWN, C.J. (Eds), *The atlas of southern African birds.* Vol. 2: Passerines. Johannesburg: BirdLife South Africa: 573-575.

MURTON, R.K., BUCHER, E.H., NORES, M., GÓMEZ, E. & REARTES, J. 1974. The ecology of the Eared Dove (*Zenaida auriculata*) in Argentina. *The Condor.* **76**: 80-88.

MURTON, R.K., ISAACSON, A.J. & WESTWOOD, N.J. 1963. The use of baits treated with α-chloralose to catch Wood-Pigeons. *Annals of Applied Biology.* **52**: 271-293.

MURTON, R.K., ISAACSON, A.J. & WESTWOOD, N.J. 1965. Capturing Columbids at the nest with stupefying baits. *Journal of Wildlife Management.* **29**: 647-649.

MURTON, R.K., THEARLE, R.J.P & THOMPSON, J. 1972. Ecological studies of the Feral Pigeon *Columba livia* Var. 1. Population, breeding biology and methods of control. *Journal of Applied Ecology.* **9**: 835-874.

MURTON, R.K., WESTWOOD, N.J. & ISAACSON, A.J. 1964a. The feeding habits of the Woodpigeon *Columba palumbus*, Stock Dove *C. oenas* and Turtle Dove *Streptopelia turtur. Ibis.* **106**: 174-188.

MURTON, R.K., WESTWOOD, N.J. & ISAACSON, A.J. 1964b. A preliminary investigation of the factors regulating population size in the Woodpigeon *Columba palumbus. Ibis.* **106**: 482-507.

MURTON, R.K., WESTWOOD, N.J. & ISAACSON, A.J. 1974. A study of Woodpigeon shooting: the exploitation of a natural animal population. *Journal of Applied Ecology.* **11**: 61-81.

NAGY, K.A. 1987. Field metabolic rate and food requirements scaling in mammals and birds. *Ecological Monograph.* **57**: 111-128.

NAKAMURA, K., SHIROTA, Y., KANEKO, T. & MATSUOKA, S. 1995. Scaring effectiveness of eyespot balloons on the Rufous Turtle Dove, *Streptopelia orientalis* (Latham), in a flight cage. *Applied Entomology and Zoology.* **30**: 383-392.

NAUDE, T.J. 1959. The quelea problem in southern Africa. *Ostrich supplement.* **3**: 264-270.

NEWTON, I. 1966. The moult of the Bullfinch *Pyrrhula pyrrhula. Ibis.* **108**: 41-67.

OSCHADLEUS, H.D. 2000. Red-billed Quelea movements in southern Africa shown by ringing recoveries in the SAFRING database. In: CHEKE, R.A., ROSENBERG, L.J. & KEISER, M.E. (Eds), *Workshop on research priorities for migrant pests of agriculture in southern Africa*. Chatham: Natural Resources Institute: 125-135.

OTIS, D.L. 1989. Damage assessments - estimation methods and sampling design. In: BRUGGERS, R.L. & ELLIOTT, C.C.H. (Eds), Quelea *quelea Africa's bird pest*. Oxford: Oxford University Press: 78-101.

PAGET-WILKES, A.H. 1924. Notes on the birds of the Grahamstown District, Cape Province, South Africa. *Ibis* 11th series. **6**: 720-763.

PALMER, T.K. 1972. The House Finch and Starling in relation to California's agriculture. In: KENDEIGH, S.C. & PINOWSKI, J. (Eds), *Productivity, population dynamics and systematics of granivorous birds*. Warszawa: Polish Scientific Publishers: 275-290.

PLESSER, H., OMASI, S. & YOM-TOV, Y. 1983. Mist nets as a means of eliminating bird damage to vineyards. *Crop Protection*. **2**: 503-506.

PORTER, D. & McLENNAN, J. 1995. A comparison of a non-toxic bird repellent and netting as methods for reducing bird damage to wine grapes. *10th Australian Vertebrate Pest Control Conference:* 341-345.

PYM, F.A.O. 1909. A list of the birds of the Kaffrarian Frontier. *Journal of the South African. Ornithologists' Union*. **5**: 91-113.

PYM, F.A.O. 1915. Birds of the Kaffrarian Frontier. *Journal of the South African Ornithologists' Union*. **11**: 29-32.

QUICKELBERGE, C.D. 1989. *Birds of the Transkei*. Durban: Durban Natural History Museum.

QUINTON, W.F. & WINTERBOTTOM, J.M. 1968. A list of the birds of the Beaufort West District. *South African Avifauna Series*. **55**: 1-18.

RAIJMAKERS, J.M.H. 1992. Colouration, size and moult in the Redheaded Finch. *Safring News*. **21**: 3-6.

RIDPATH, M.G., THEARLE, R.J.P., McCOWAN, D. & JONES, F.J.S. 1961. Experiments on the value of stupefying and lethal substances in the control of harmful birds. *Annals of Applied Biology*. **49**: 77-101.

RODRIGUEZ, E.N. & AVERY, M.L. 1996. *Agelaius* blackbirds and rice in Uruguay and the southeastern United States. *Proceedings of the 17th Vertebrate Pest Conference*: 94-98.

RODRIGUEZ, E.N., BRUGGERS, R.L., BULLARD, R.W. & COOK, R. 1997. An integrated strategy to decrease Eared Dove damage in sunflower crops. In: MASON, J. (Ed.), *Repellents in Wildlife Management.* Fort Collins, CO: USDA, National Wildlife Research Centre: 409-421.

ROTHERY, P., WYLLIE, I., NEWTON, I., DAWSON, A. & OSBORN, D. 2001. The timing and duration of moult in adult Starlings *Sturnus vulgaris* in east-central England. *Ibis.* **143**: 435-441.

ROUX, P.W. & VAN DER VYVER, J. 1988. The agricultural potential of the Eastern Cape and Cape Midlands. In: BRUTON, M.N. & GESS, F.W. (Eds), *Towards an environmental plan for the Eastern Cape.* Grahamstown: Rhodes University: 100-125.

ROWAN, M.K. 1969. The foods of South African birds. *Ostrich supplement.* **8**: 343-356.

ROWAN, M.K. 1983. *The doves, parrots, louries & cuckoos of southern Africa.* Cape Town: David Philip.

ROYALL, W.C. Jr., DeCINO, T.J. & BESSER, J.F. 1967. Reduction of a starling population at a turkey farm. *Poultry Science.* **46**: 1494-1495.

SCHLUPP, W.F. 1922. The graniverous bird problem. *Journal of the Department of Agriculture.* **4**: 432-446.

SIRIWARDENA, G.M., BAILLIE, S.R. & WILSON, J.D. 1999. Temporal variation in the annual survival rates of six granivorous birds with contrasting population trends. *Ibis.* **141**: 621-636.

SKEAD, C.J. 1946a. One years' census study of birds in 2.5 acres of Albany bushveld April 1944 to March 1945. *Ostrich.* **17**: 87-100.

SKEAD, C.J. 1946b. A census and study of birds in Albany open thornbushveld. *Ostrich.* **17**: 213-221.

SKEAD, C.J. 1946c. A census study of birds in Albany open sour grassveld. *Ostrich.* **17**: 222-231.

SKEAD, C.J. 1947. One year's census and study of birds in 2.5 acres of Albany bushveld April 1945 to March 1946. *Ostrich.* **18**: 155-165.

SKEAD, C.J. 1956. A study of the Red Bishop Bird, *Euplectes o. orix.* *Ostrich.* **27**: 112-126.

SKEAD, C.J. 1965a. The ecology of the ploceid weavers, widows and bishop-birds in the south-eastern Cape Province, South Africa. In: DAVIES, D.H.S. (Ed.), *Ecological studies in southern Africa.* Vol. XIV. The Hague: W.H. Junk: 219-232.

SKEAD, C.J. 1965b. Birds of the Albany (Grahamstown) District. *South African Avifauna Series.* **30**: 1-46.

SKEAD, C.J. 1967. Ecology of birds in the Eastern Cape province. *Ostrich supplement.* **7**: 1-103.

SKEAD, C.J. 1995. *Life-history notes on East Cape bird species (1940-1990).* Vol. 1. Port Elizabeth: Algoa Regional Services Council.

SMIT, N.S. 1996. Verbouing van durumkoring in die Visriviervallei. *Döhne Bulletin.* **5**: 6-7.

SOOBRAMONEY, S. 1998. An investigation into the ageing techniques and feeding ecology of the Redbilled Quelea *Quelea quelea.* Unpublished M.Sc. Thesis, University of Durban-Westville, Durban, Republic of South Africa.

STARK, A.C. 1900. *The birds of South Africa.* Vol. 1. London: R.H. Porter.

STEELE, G.R., WHITTINGTON-JONES, C.A. & CRAIG, A.J.F.K. 1999. Testing chemical markers on granivorous birds. *South African Journal of Science.* **95**: 79-80.

STOUFFER, P.C. & CACCAMISE, D.F. 1991. Capturing American Crows using alpha-chloralose. *Journal of Field Ornithology.* **62**: 450-453.

SUTHERS, H.B. 1978. Analysis of a resident flock of starlings. *Bird-banding.* **49**: 35-46.

SWADDLE, J.P. & WITTER, M.S. 1997. Food availability and primary feather moult in European Starlings, *Sturnus vulgaris. Canadian Journal of Zoology.* **75**: 948-953.

TARIMO, T. 1999. Dhurin: A cyanogenic glycocide: Possible cause of bird-resistance in ARK-3048 sorghum. *Research Priorities of the Workshop on Migrant Pests of Agriculture in Southern Africa*: p19.

TAYLOR, J.S. 1964. The birds of Fort Beaufort and Adelaide, C.P. *South African Avifauna Series.* **22**: 1-40.

THEARLE, R.J.P. 1969. Some problems involved in the use of stupefying baits to control birds. *Proceedings of the 5th British Insecticide and Fungicide Conference*: 458-464.

THOMAS, H.M., SIMPSON, D. & PRESCOTT, L.F. 1988. The toxic effects of alpha-chloralose. *Human Toxicology.* **7**: 285-287.

THOMPSON, J.J. 1988. The post-nuptial moult of *Quelea quelea* in relation to breeding in Kenya. *Journal of Tropical Ecology.* **4**: 373-380.

TINNEY, G.M. 1997. *Influence of temperature on the metabolism of the Red-billed Quelea (Quelea quelea): Implications for extending distribution.* Unpublished B.Sc. Honours thesis, Rhodes University, Grahamstown, Republic of South Africa.

TOOR, H.S., KAUR, H. & DHINDSA, M.S. 1986. Community structure and feeding ecology of birds at a grain store in Punjab (India). *Tropical Science.* **26**: 233-247.

TREE, A.J. 1965. On the Red-headed Quelea, *Quelea erythrops* (Hartlaub) in Zambia. *Bulletin of the British Ornithologists' Club.* **85**: 159-161.

TREE, A.J. 1972. Ornithological comparison between differing dry seasons at a pan in Botswana. *Ostrich.* **43**: 165-168.

TREE, A.J. 1989. Movements of the Quelea in Zimbabwe. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), *Africa's Feathered Locust.* Harare: Baobab Books: 84-89.

TWEDT, D.J. 1980. Control netting as a hazard to birds. *Environmental Conservation.* **7**: 17-218.

TWEDT, D.J., BLEIER, W.J. & LINZ, G.M. 1991. Geographic and temporal variation in the diet of Yellow-headed Blackbirds. *The Condor.* **93**: 975-986.

TYLER, P.S. 1979. Birds as pests of food stores. *Tropical Stored Products Information.* **37**: 19-24.

UNDERHILL, L.G. 1998. Redbilled Queleas breeding at the Orange River estuary. *Bird Numbers.* **7(2)**: 23.

UNDERHILL, L.G. 2000. An introduction to primary moult. *Safring News.* **29**: 44-46.

UNDERHILL, L.G. & UNDERHILL, G.D. 1997. Primary moult, mass and movements of the Rock Pigeon *Columba guinea* in the Western Cape, South Africa. *Ostrich.* **68**: 86-89.

UNDERHILL, L.G. & ZUCCHINI, W. 1988. A model for avian primary moult. *Ibis.* **130**: 358-372.

VAN DER WALT, E. 1998. Environmental risks uncovered during Redbilled Quelea (*Quelea quelea*) control. *Plant Protection News.* **52**: 6-9.

VERNON, C.J. 1989. The quelea in natural ecosystems. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), *Africa's feathered locust.* Harare: Baobab Books: 14-17.

VICKERS, M.L. & HANSON, R.P. 1979. Experimental Newcastle Disease virus infections in three species of wild birds. *Avian Diseases.* **23**: 70-79.

WARD, P. 1964. The war against the quelea bird. *New Scientist.* **396**: 736-738.

WARD, P. 1965. Feeding ecology of the Black-faced Dioch *Quelea quelea* in Nigeria. *Ibis.* **107**: 173-214.

WARD, P. 1966. Distribution, systematics, and polymorphism of the African weaver-bird *Quelea quelea. Ibis.* **108**: 34-40.

WARD, P. 1971. The migration patterns of *Quelea quelea* in Africa. *Ibis.* **113**: 275-297.

WARD, P. 1973a. A new strategy for the control of damage by queleas. *Pest Articles and News Summaries.* **19**: 97-106.

WARD, P. 1973b. Manual of techniques used in research on quelea birds. UNDP/FAO publication: Rome.

WARD, P. 1978. The role of the crop among Red-billed Queleas *Quelea quelea. Ibis.* **120**: 333-337.

WARD, P. 1979. Rational strategies for the control of queleas and other migrant pests in Africa. *Philosophical Transactions of the Royal Society of London B.* **287**: 289-300.

WARD, P. & JONES, P.J. 1977. Pre-migratory fattening in three races of the Red-billed quelea *Quelea quelea* (Aves: Ploceidae), an intra-tropical migrant. *Journal of Zoology (London).* **181**: 43-56.

WARD, P. & ZAHAVI, A. 1973. The importance of certain assemblages of birds as "information-centres" for food-finding. *Ibis.* **115**: 517-534.

WEATHERHEAD, P.J., TINKER, S. & GREENWOOD, H. 1982. Indirect assessment of avian damage to agriculture. *Journal of Applied Ecology.* **19**: 773-782.

WEBSTER, K. 1994. Notes from Rookwood. *Bee-eater.* **45**: 53.

WEST, R.R. 1968. Reduction of a winter starling population by baiting its preroosting areas. *Journal of Wildlife Management.* **32**: 637-640.

WEST, R.R., BESSER, J.F. & DE GRAZIO, J.W. 1967. Starling control in livestock feeding areas. *Proceedings of the 3rd Vertebrate Pest Conference*: 89-93.

WHITTINGTON-JONES, C.A. 1997. Apparent range expansion of the Redbilled Quelea *Quelea quelea* in the Eastern Cape Province of South Africa. *Ostrich.* **68**: 97-103.

WIENS, J.A. & DYER, M.I. 1975. Simulation modelling of Red-winged Blackbird impact on grain crops. *Journal of Applied Ecology.* **12**: 63-82.

WILLIAMS, D.E. & CORRIGAN, R.M. 1994. Pigeons (Rock Doves). In: HYGNSTROM, S.E., TIMM, R.M. & LARSON, G.E. (Eds), *Prevention and control of Wildlife damage.* Lincoln: University of Nebraska Cooperative Extension Division: E87-E96.

WILLIAMS, L.E. & PHILLIPS, R.W. 1972. Test of oral anesthetics to capture Mourning Doves and Bobwhites. *Journal of Wildlife Management.* **36**: 968-971.

WINKFIELD, R.A. 1989. The distribution and importance of small-grain crops in Zimbabwe and their susceptibility to quelea damage. In: MUNDY, P.J. & JARVIS, M.J.F. (Eds), *Africa's feathered locust.* Harare: Baobab Books: 100-103.

WINTERBOTTOM, J.M. & HARE, H.L. 1947. On the birds of Port St. Johns, Pondoland. *Ostrich.* **18**: 86-102.

WOODBURY, C.J. 1961. Local control of crows by trapping. *Journal of Agriculture Western Australia.* **2**: 33-35.

WORONECKI, P.P. & DOLBEER, R.A. 1994. Alpha-chloralose: Current status, restrictions and future uses for capturing birds. *Proceedings of the 16th Vertebrate Pest Conference*: 255-258.

WORONECKI, P.P., DOLBEER, R.A. & SEAMANS, T.W. 1990. Use of alpha-chloralose to remove waterfowl from nuisance and damage situations. *Proceedings of the 14th Vertebrate Pest Conference*: 343-349.

WORONECKI, P.P., DOLBEER, R.A., SEAMANS, T.W. & LANCE, W.R. 1992. Alpha-chloralose efficacy in capturing nuisance waterfowl and pigeons and current status of FDA registration. *Proceedings of the 15th Vertebrate Pest Conference*: 72-78.

YELD, J. 1993. The quelea problem. *African Wildlife.* **47**: 112-115.

YOKOYAMA, H. & NAKAMURA, K. 1993. Aversive response of Tree Sparrows *Passer montanus* to distress call and the sound of paper flag. *Applied Entomology and Zoology.* **28**: 359-370.