CROP PROTECTION PROGRAMME

Quelea birds in Southern Africa: protocols for environmental assessment of control and models for breeding forecasts

R8314

FINAL TECHNICAL REPORT

1 April 2003 - 31 March 2005

Project Leader R. A. Cheke

Plant, Animal & Human Health Group, Natural Resources Institute, University of Greenwich at Medway, Central Avenue, Chatham Maritime, Kent ME4 4TB

15 June 2005

This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID. R8314 Crop Protection Programme

Executive Summary

The project's purpose was to generate benefits for poor people by application of new knowledge to control of migrant pests in semi-arid systems. This was achieved by research activities involving (a) environmental impact assessments (EIAs) of quelea bird control in southern Africa; (b) training collaborating staff in EIA methods; (c) continuation of a modelling programme for forecasting quelea bird breeding opportunities; (d) transfer of the modelling technology to users in Africa; (e) updating a website with the forecasts and quelea information on it and (f) investigating the potential of community-based control whereby villagers harvest the birds for food.

A training course in EIA with 16 attendees was conducted in Gaborone, followed by field-based training. An EIA of effects of ground-spraying a breeding colony of the Red-billed Quelea *Quelea quelea* with 4l/ha of fenthion, an organophosphate avicide, revealed up to 1.52 mg/kg of fenthion in soil samples the day after spraying. Nearly 50% of a treatment dose was still recoverable in soil a week after application. No differences were found in pre- and post-spray populations of non-target birds estimated by timed bird count and line transect methods. However, significant depressions of both acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) levels in the blood of target quelea birds and in samples from non-target birds were demonstrated. The high percentage depression (64 to 88%) found among quelea and the low ChE values of the non-target species from the sprayed colony confirm the utility of this assay, conducted with a novel purpose-built field kit, for assessing fenthion poisoning. Such poisoning was probably responsible for the death of a male Red-backed Shrike *Lanius collurio* and the moribund condition of four non-target birds of three other species. During the study, the first of acetylcholinesterase levels in African birds, background levels in 32 species were recorded which will form the basis of a data-base with which future post-control assessments can be compared.

An EIA was also conducted of the control of a quelea bird roost with explosives. This involved the detonation of 233 5-litre plastic containers, each filled with 2l of diesel and 2l of petrol. Apart from a 90% kill of the target birds, 3 non-target birds and 4 non-target mammals were also killed but no significant differences were found in pre- and post-explosion censuses of non-target bird populations. However, analyses of soil samples revealed concentrations of up to 9.31 mg/kg of diesel and residues of dibutyl phthalate, presumably phthalates derived from the plastic containers used.

Protocols for similar studies and censuses to obtain comparative data in different seasons and at different locations are proposed and recommendations are made on best practice to reduce unnecessary pollution levels.

The quelea forecasting model was transferred to the Remote Sensing Unit of SADC and the website was updated with soil, vegetation and watercourse maps to aid forecasting based on rainfall estimates.

A possible alternative to sprays and explosions, the harvesting of quelea bird nestlings as food for people was investigated in the Bobonong area of Botswana. A consensus of all interviewees in three different villages was emphatic in favour of community-based harvesting measures rather than the use of sprays or explosives. Constraints identified that hindered more widespread use of the method were lack of transport from the villages to the colonies, the existing policy of spraying, lack of knowledge on means to preserve the birds and a lack of identifiable markets or means to reach potential markets.

CONTENTS Page No.

1. Background

Small-grain cereal crops throughout semi-arid areas of Africa are subject to damage by the Red-billed Quelea bird *Quelea quelea* of up to US$45 million per annum (Elliott 1989). Control of concentrations of thousands of the birds, gathered in breeding colonies or nocturnal roosts, involves aerial application of organophosphate pesticides or fire-bombs created by the detonation with explosives of mixtures of diesel and petrol. The environmental impact of these activities has not been adequately researched but it is recognised that means to minimise the effects are required. Another researchable constraint is the difficulty of knowing where and when the birds will occur and where they will require control in the extensive semi-arid regions that they live in. This difficulty arises mainly because quelea are migratory, moving in relation to the timing and distribution of rainfall and the availability of annual grass seeds, the birds' principal food (Ward 1971, Jones 1989a,b). Genetically homogenous populations of the subspecies *Q. q. lathamii* migrate throughout the southern African region. In addition to demonstrating their genetic uniformity (Dallimer *et al.* 2003), CPP-funded research has developed a model for forecasting where and when the birds could breed in southern Africa (Jones *et al.* 2000 and see ITR for R7967 and FTR for R6823). The model forecasts the timing and locations of suitable sites where quelea breeding colonies could require control to prevent successful fledging of juveniles. The model uses satellite-derived estimates of rainfall to determine when the threshold quantity of rainfall (60-70 mm, estimated from the duration of cold cloud at –38°C or below) has been exceeded at any time within a two-week period. This quantity is required to cause grass seed germination and hence to initiate the "early rains migration" by the birds out of their dry season quarters. When sufficient time (6 weeks) has elapsed since the germination of the grass seeds, the satellite data are again used to determine whether sufficient rainfall (240mm) has fallen to allow the birds to begin breeding.

Birds threatening crops are controlled by aerial spraying of their breeding colonies with the avicide fenthion or by the use of explosives to destroy nocturnal roosts. Although neither method is without environmental impact and mortality to non-target species, there has been particular concern for avian conservation over use of chemical sprays where non-target birds could be contaminated. Thus, the environmental impact of such control and of the use of explosives required to be investigated with a view to recommending means of minimising it. As there are no standard protocols or codes of practice established within Africa to ensure that environmental damage is minimised, the project aimed to devise such protocols for biodiversity assessment (vertebrates and invertebrates) and evaluation of potential ecological damage, to be used before and after quelea control operations and to enhance the capacity of national organisations to implement the policies. Another project objective was to investigate an alternative to sprays and explosions, the harvesting of quelea bird nestlings as food for people. The most widespread method of harvesting quelea is the collection of nestlings from breeding colonies, which is most productive just before they fledge. Demand for the above was identified through regional discussions, including through the related ICOSAMP project and with SADC, and via national authorities such as the Ministry of Agriculture of Botswana.

2. Project Purpose

The purpose of the project was to generate benefits for poor people by applying new knowledge to control of migrant pests in semi-arid systems. Control of migrant pests benefits the livelihoods of farmers by protecting their crops from destruction. The research and training described in this report contributed to that objective indirectly by seeking to make control of quelea birds more efficient and less damaging to the environment. An improved forecasting system was developed and handed over to SADC for regional dissemination and it was also made available on the ICOSAMP and NRI websites. Field studies in Botswana addressed the problem of environmental impacts of quelea control by spraying and by explosives and led to the drafting of protocols for discussion amongst stakeholders with a view to standardising procedures. Thus the project contributed to strengthening (a) regional capacity to produce and disseminate forecasting information and (b) regional capacity to develop and promote environmentally effective control measures.

3. Research Activities

3.1. Report on activities to achieve output 1. Capacity of target institution staff to conduct environmental monitoring of quelea control enhanced.

3.1.1. *Training course in assessment methods conducted in Botswana*

A week-long training course on *Environmental impact assessment of quelea bird control* was run by R. A. Cheke and A. N. McWilliam at Sebele, near Gaborone, Botswana from 16 to 21 February 2004. The course consisted of formal lectures and practical work in the field, including a visit to a recently controlled quelea breeding colony. The programme is given in Table 3. 1. 1.

Thirteen members of the Plant Protection Division of the Ministry of Agriculture attended. They included the Head of the Pesticide Management Section, the Head of the Pest Management Section, three Regional Plant Protection Officers, four District Plant Protection officers and two Agricultural Scientific Officers (see Table 3. 1. 2).

All attending trainees were given copies of (a) Grant, I. F. & Tingle, C. D. (eds.) (2002) *Ecological Monitoring Methods for the Assessment of Pesticide Impact in the Tropics. Handbook and Methods Sheets*, Natural Resources Institute, Chatham UK, as the basic text for methods of monitoring non-target invertebrates and vertebrates, especially birds and reptiles, in conjunction with field-work, and (b) Allan, R. G. 1997. *The Grain-eating Birds of Sub-Saharan Africa. Identification, Biology and Management*. Natural Resources Institute, Chatham, UK. Prior to the course commencement, the trainees were asked to complete a questionnaire on their skills in the subject (Table 3. 1. 3.). One afternoon training session on vegetation classification was conducted in scrubland near Sebele, other practical sessions took place on open ground and grassland near the lecture room and a visit was made to a quelea breeding colony at Maselelo (24° 34.874'S, 25° 57.771'E) in the Segakwana area, NE of Gaborone. This 89ha colony in *Acacia tortilis* was being controlled from the ground with explosives to protect a large field of sorghum 200 m away from the colony. All course members were shown how this was done and a demonstration of the use of a mist-net for catching birds was also conducted. After completion of the course, all attendees were given certificates.

To judge whether the objective of "Capacity of target institution staff to conduct environmental monitoring of quelea control enhanced" had been achieved a

questionnaire (Table 3. 1. 4) was completed by the trainees after the course. The responses were very favourable and copies are available on request.

3.1.2. *Evaluation of trainees in practical assessments in controlled quelea colonies in Botswana (Jan-Mar 2004 & Jan–Mar 2005).*

Collen Mbereke, one of the trainees, was assigned to EIA duties, and he accompanied project members in the field in both 2004 and 2005. During the field work this officer was further trained in pre-and post-control EIA procedures. He had opportunities to put his skills into practice, and have them evaluated, at a quelea breeding colony sprayed with fenthion in March 2004 and at a quelea roost controlled with explosives in March 2005. In addition, he was given appropriate equipment and training to continue EIA work in Botswana. After the field work, Mr Mbereke was proficient in site mapping, vegetation surveying, soil sampling and procedures for assessing acetylcholinesterase levels in birds.

Table 3.1.1. Training course programme.

TRAINING COURSE

ENVIRONMENTAL IMPACT ASSESSMENT OF QUELEA BIRD CONTROL

Centre for Inservice and Continuing Education (CICE) of the Botswana College of Agriculture, Sebele, near Gaborone

Programme

Monday 16 February
0900 Visit Sebele and venue
1400 Course starts. Introduction
Aims of the Course (RAC)
Introduction to EIA and Toxicology (AMcW)
Video (1 Hour)

Tuesday 17 February
0900 Introduction to the Manual (RAC)
Planning and programme design (RAC)
Quelea EIA (AMcW & RAC Discussion of paper on Quelea EIA to be published in *Environmental Conservation*)
Study Design: Sampling, randomisation, pseudo-replication and data analysis (RAC)
Residue Sampling (AMcW)
Introduction to the afternoon's practical sessions
1200 end
1400-1600 Practical
Vegetative cover and shade (4 groups)
Residue Sampling

Wednesday 18 February
0900 Survey methods: terrestrial invertebrates (RAC)
Environmental parameters (AMcW)
1400-1600 Practical: Invertebrates
Sweep Netting
Pitfall trapping
Malaise trapping
Butterfly transects

Thursday 19 February
0900 Survey methods: vertebrates
Birds (RAC)
Amphibians and reptiles (AMcW)
1400-1600 Practical: Vertebrates
Visual encounter surveying: amphibians and reptiles
Complete species inventoring: amphibians and reptiles
Quadrat and transect block micro-habitat sampling
Timed point counts: birds
Transect counts: birds

Friday 20 February
0900 Safety (RAC)
Acetylcholinesterase kits (AMcW)

1400-1600 Round-up & Discussion of Topics not covered previously

Table 3. 1. 2. Details of the trainees

Environmental Impact Assessment Training Course

Trainees- The following are the names, positions and qualifications of the trainees invited to attend. Some of the proposed trainees, marked with an *, did not attend the course because of commitments with control operations. The Plant Protection officers based at the regions and district have similar roles since they attend to all plant protection issues at their areas of operation. Those at headquarters are attached to specific sections but all of them are responsible for Quelea control activities.

Name	Position	Qualification	Location
*Super Suveree Kapeko	Regional Plant Protection Officer	Diploma in Agriculture	Maun (Ngamiland Region)
Sabata Oboletse	District Plant Protection officer	Diploma in Agriculture	Kasane (Ngamiland Region)
*Bangwe Baliki	District Plant protection Officer	Diploma in Agriculture	Tutume (F/town Region)
Pius Malikongwa	Regional Plant Protection Officer	BSc Agriculture	Francistown
*Simane Rathoakgale	Regional Plant Protection Officer	BSc Agriculture	Serowe (Central Region)
Patrick Boitshwarelo	District Plant Protection Officer	Diploma in Agriculture	Serowe
Thabakgolo Onalenna	District Plant Protection Officer	Diploma in Agriculture	Selibephikwe (Central Region)
Modisaotsile Mabutho	District Plant Protection Officer	Diploma in Agriculture	Mahalapye (Central Region)
*Loitseng Sebetwane	Regional Plant Protection Officer	BSc Agriculture	Gaborone (Gaborone Region)
*Olefile Dinne	District Plant Officer	Diploma in Agriculture	Molepolole (Gaborone Region)
Hendrick Modiakgotla	Regional Plant Protection Officer	BSc Agriculture	Kanye (Southern Region)
Malebogo Malele	Agricultural Scientific Officer	BSc Agriculture	Sebele (Pest management)
Mosinyi Mmopi	Plant Protection Officer	Diploma in Agriculture	Sebele (Pest Management Section)
Patience Mawere	Agricultural Scientific Officer	BSc Agriculture, MSc Microbiology	Sebele
Kgasiduntsi Norman Kgary	Superintendent	Diploma, Mechanization	Sebele
Collen Mbereki	Agricultural ScientificOfficer	BSc Agriculture	Sebele (Pesticide Management Section
Tshipo Moruti	Head Pest Management Section	MSc Crop Protection	Sebele
Rebecca Kgosi	Head Pesticide Management Section	MSc Crop Protection	Sebele

Table 3. 1. 3. Pre-Course questionnaire.

Environmental Impact Assessment Training Course

Please rate your knowledge and experience of the following topics as either:

A: *EXCELLENT*; B: *VERY GOOD*; C: *GOOD*; D: *POOR*: E: *NIL*

1. ENVIRONMENTAL IMPACT ASSESSMENT IN GENERAL
2. ENVIRONMENTAL IMPACT ASSESSMENT OF QUELEA BIRDS
3. CONTROL OPERATIONS
4. CONTROL OF QUELEA BIRDS WITH QUELETOX
5. CONTROL OF QUELEA BIRDS WITH EXPLOSIVES
6. IDENTIFICATION OF MAMMALS IN BOTSWANA
7. IDENTIFICATION OF BIRDS IN BOTSWANA
8. IDENTIFICATION OF INSECTS IN BOTSWANA
9. ANIMAL POPULATION MONITORING
10. VEGETATION SURVEYS

11. DO YOU HAVE ACCESS TO A COMPUTER WITH INTERNET ACCESS (A) DAILY (B) OFTEN (C) OCCASIONALLY (D) NEVER?

12. DO YOU HAVE ACCESS TO A COMPUTER WITHOUT INTERNET ACCESS (A) DAILY (B) OFTEN (C) OCCASIONALLY (D) NEVER?

Table 3. 1. 4. Course Evaluation Form

UNIVERSITY OF GREENWICH AT Medway

Course Evaluation Form

Course title: **Course Leader**:	Instructions: Using the headings as a guide, please comment on the course. It would help us if you could include positive points as well as negative points or areas for improvement. Please continue over the page if necessary.
1. Facilities (i.e. teaching accommodation, library, laboratories, IT etc)	
2. General communication (ease of contacting and speaking to lecturers, general presentation of course material etc)	
3. Organisation of course	
4. Intellectual challenge of the course	
5. Visual aids	
6. Overall quality of course and additional comments	

3.2. Report on activities to achieve output 2. Field evaluation of environmental impact of quelea control in Botswana.

3.2.1. *Data on environmental effects of quelea control obtained during field work in Botswana.*

3.2.1.1. Effects of spraying with fenthion

3.2.1.1.1. INTRODUCTION

The Red-billed Quelea *Quelea quelea* is a major pest of agriculture in sub-Saharan Africa, causing damage to small-grain cereal crops in particular. Annual losses to this pest, which does not occur outside Africa, have been estimated to be as high as US$45 million (Elliott 1989). In South Africa, wheat, sorghum, millet and sunflower crops are often affected and, in 1997-1998 SA Rand 2,790,000 were spent controlling the pest there. However, the control actions were estimated to have prevented SA Rand 10,523,200 of crop damage (Geertsema 1998). The Red-billed Quelea is also a major pest in Botswana, where control is required annually. The extent of the control actions needed vary from year to year as the bird is a migrant pest, dependent for its breeding success on the rainfall regime during a particular season. Also, the locations where the birds occur will vary from season to season. However, the zones where the birds can breed are predictable to some extent, on the basis of a particular year's rainfall patterns (Jones *et al.* 2000, Venn *et al.* 2003). This is possible partly because the populations in southern Africa, the subspecies *Q. q. lathamii*, can be treated as one interbreeding group that lacks genetic differentiation (Dallimer *et al.* 2003). The Red-billed Quelea is gregarious, occurring in flocks that gather to roost, migrate and to breed. Both roosting groups and breeding colonies can be huge with more than 25,000,000 birds in them and, as such, pose discrete targets for control actions.

Control of quelea birds usually involves spraying with lethal concentrations of pesticides (e.g. the organophosphates fenthion or cyanophos) or the use of explosives to destroy roosts and, occasionally, breeding colonies too. Such measures are not without environmental consequences and their effects on non-target organisms have recently been reviewed by McWilliam & Cheke (2004). In view of the potential environmental effects of quelea spraying, an environmental impact assessment of the use of fenthion against quelea birds was conducted in a colony near Francistown, Botswana, in February-March 2004. The assessment involved analyses of data and material collected both before and after the spraying operation. Three topics were investigated: (1) non-target bird populations; (2) assessment of exposure to fenthion in birds according to their cholinesterase levels and (3) fenthion concentrations in the soil.

Bird populations are difficult to assess in short-term studies, as means to detect them such as records of singing by territorial males or conspicuous displays may be seasonal and related to breeding activities. Similarly, in a rapid assessment it is not possible to calculate population estimates based on capture-recapture studies or nesting densities. Nevertheless, some information can be gleaned by a combination of point counts and transects and both these methods were used in this study.

In both invertebrates and vertebrates, organophosphates (OPs) and carbamates act by inhibiting (phosphorylating or carbamating) acetlycholinesterase, an enzyme essential for normal nerve function (Coye *et al*. 1986, Magnotti *et al.* 1988). In the

body acetylcholinesterase, which is present in the postsynaptic membranes of cholinergic synapses, inactivates the chemical messenger acetylcholine, which is active at the junctions between nerves and muscles. Inhibition of the enzyme results in build-up of acetylcholine and prolonged transmission of nerve impulses, in both central and peripheral nervous systems, leading to tetanus and death by asphyxiation from respiratory failure. While it is the inhibition of acetylcholinesterase in the nervous system that is responsible for toxicity, similar types of cholinesterase exist in both blood cells and plasma and can be used as markers of exposure to OPs and carbamates. Red blood cell acetylcholinesterase, also called erythrocyte cholinesterase, is commonly identified as AChE. Plasma cholinesterase, also called pseudocholinesterase or buterylcholinesterase, is commonly identified as PChE or BChE and is a very sensitive measure of exposure (Thompson 1999). Levels of inhibition of AChE and PChE provide slightly different information and both assays can provide useful information as part of an environmental impact assessment (EIA), their levels of inhibition being proportional to exposure to the pesticide. Red blood cell AChE is identical to the enzyme found in the nervous system, and it is thought to be a good indicator of neuronal activity. The turnover rate for red blood cells is slow (half-life of about 1 month) and AChE is typically used as a marker of chronic exposure. In contrast, PChE turnover is much quicker (half-life of about 2 weeks) and it is a better short-term indicator due to its more rapid response to exposure (Whitaker 1986, Lawson & Barr 1987).

Contamination of soil with high concentrations of pesticides can lead to death of soil-dwelling invertebrates and interference with ecosystem functioning. However, unless exposed to repeated contamination, ecosystems will recover in the long-term, especially if the pesticides involved break down quickly. There is, however, a paucity of information on the effects of fenthion on soil in relation to quelea control activities. It is known from a study in South Africa that shortly after application, residues in soil ranged from 1-3 mg/kg, but the day after spraying residues in soil invertebrates exceeded 45 mg/kg and persisted for up to 42 days (van der Walt 2000). Perhaps of greater concern than the short-term effects, monitored in this study, would be the effects of repeated exposures at sites that are sprayed regularly.

Partly on the basis of the experience gained during this study and that on explosive control (see section 3.2.1.2.), a set of protocols that could be followed routinely by monitoring teams are proposed in section 3.3.1. These procedures could shed light on the long-term impacts of the lethal control of Red-billed Quelea if they were used systematically each season for some years.

3.2.1.1.2. STUDY SITE AND METHODS

Study Site

A quelea colony at Sebalola (21°12'4''S, 27°02'27''E [21°20.063'S, 27°04.446'E, GPS coordinates]), approximately 50 km west-southwest of Francistown was selected for the study. The dominant vegetation where the birds were nesting was *Acacia mellifera*, with *A. tortilis*. Other plant species present included *Combretum apiculatum, Grewia bicolor, G. flavescens*, *Boschia* sp. and *Colophospermum mopane*. The quelea birds were threatening a sorghum plantation about 4km away. The majority of quelea nests contained young hatchlings when first inspected on 29 February.

Tracks were cut through the vegetation in which the birds were breeding by the control team of the Plant Protection Division of the Botswana Ministry of Agriculture

to allow access for the spray vehicles. The colony was sprayed on 3 March 2004 with 4l/ha of fenthion, applied by vehicle-mounted mist-blow sprayers.

Bird Surveys

A combination of line transects and point counts for fixed times was used (Bibby *et al.* 1992). The cuts made by the control teams through the colony were used to form the basis of the line transects, which were surveyed for birds before and after the spraying. Five points for timed bird counts and five transects, each of 100m in length, were marked with tape along the length of the path (Figure 3.2.1.1.1). The first transect began 20m after the site for the first timed bird count and 40m were left as gaps between the end of one transect and the beginning of the next. Positions for point counts 2-5 were half way along the gaps between the line transects, i.e. 20m from the end of one and 20m from the beginning of the next. For the timed bird counts, all birds heard or seen during five minute periods were noted. For the line transects, similar data were recorded when the transects were traversed at a slow, but constant, walking pace. In both cases care was taken not to count individual birds twice.

Cholinesterase levels in birds

To obtain estimates of background levels of red blood cell acetylcholinesterase (AChE) and plasma cholinesterase (BChE), samples of blood were taken from a random selection of birds that had not been exposed to fenthion spraying. These were caught at sites near Gaborone (24° 45'S, 25°51'E), near Shakawe (18° 22'S, 21° 51'E), and at Kotoloname (24°28'20'S, 25°16'33"E), as well as before the spraying at Sebalola. Birds were trapped in mist-nets and blood extracted into 10μl capillary tubes, following puncture of their brachial veins with sterilised finger-stick needles and swabbing of the wound with absolute alcohol. The same procedure was conducted on moribund birds caught by hand after the spraying. Birds were held in cloth bags and released after measurements of wing length (mm, measured with a stopped rule) and weight (g, measured using a Pesola balance). In addition, blood was taken before and after the spraying from two nestling Laughing Doves *Streptopelia senegalensis* (about a week old) that were found in a nest near the colony.

A custom-made kit, the EQM field test kit developed by Patrick Eberly, was used for the assays. The kit is a complete, self-contained and portable cholinesterase testing system (EQM Research, Inc. Cincinnati, USA). It uses a 12V battery-operated colorimeter, based on the Ellman method (Ellman *et al.* 1961), and a photometric analyser to measure the concentration of an indicator that increases in proportion to the activity of cholinesterase in test samples. The assay kit measures both PChE and AChE (corrected for temperature and haemoglobin levels). Blood was buffered in the field with a mixture containing phosphate, surfactant and EDTA preservative and stored in a portable refrigerator at about 3^{o}C for up to 24 hours before measurement. Acetylthiocholine (AcTC) or butyrylthiocholine (BuTC) is hydrolysed by AChE or PChE, producing carboxylic acid and thiocholine which reacts with the Ellman reagent (dithionitrobenzoic acid) to form a yellow colour. This is measured spectrophotometrically at 450nm and the rate of colour formation is proportional to the amount of either AChE or PChE.

Fenthion residues in the soil

Pre-and post-control samples of soil were taken for subsequent analyses. Four samples were collected close to each of the five locations used for the point counts, providing 20 pre-spray (1 March 2004) and 20 post-spray samples taken a day after control (4 March 2004). The exact locations for the samples were 5m away from the positions for the point counts in directions determined from randomised selections of

three compass intervals (due north, 120° and 240°). The samples of approximately uniform volumes (approximately 200g, maximum depth 10cm) were taken using trowels (washed after each sampling) and stored in cloth bags before and after the spraying. They were then air-dried, sieved and any vegetable material present was removed prior to the samples being double-wrapped in aluminium foil and sealed within polythene bags. All layers were labelled with the sample details before shipment to the UK, where they were placed in a deep freeze (-18 °C) pending analysis, which commenced on 24 April 2004. After the soil samples were de-frosted prior to extraction of the pesticide residues, they were allowed to warm to room temperature. Each sample was then thoroughly mixed and a 50g sub–sample, placed into a cellulose extraction thimble (Whatman), and extracted with acetone in a Soxhlet apparatus for four hours. Each extract was then evaporated to just dryness using a rotary vacuum evaporator at 40°C with the final traces of solvent being removed under a gentle air stream. The residue was re-dissolved in hexane and quantitatively transferred to a 10ml volumetric flask and the volume adjusted to the mark. 1-2g of anhydrous sodium sulphate was then added to each flask to absorb any residual moisture. All extracts were stored in a refrigerator at < 4°C pending analysis by Gas Liquid Chromatography (GLC) using an HP 6890 Instrument fitted with a Nitrogen Phosphorus detection system, with Model HP7683 autosampler. Data collection and handling were performed using Ezichrom Elite data handling software (v3) and sample residues were calculated using a calculation factor. The capillary column used was 30m DB5, 0.25mm internal diameter and 0.25µm film thickness. A ramp rate of 25°C/min. was used with a carrier gas flow rate of 2.6 ml/min. and a retention time of 14 min.

Reference standard solutions were prepared using a fenthion certified reference standard provided by QM_x laboratories (Dr Ehrenstorfer). A primary solution at a corrected concentration of 0.961mg/ml was prepared in acetone. Intermediate solutions of 96.1 and 9.61µg/ml were prepared from the primary solution and analytical reference solutions were used at concentrations of 0.24, 0.48, 0.96 and 1.92 µg/ml. The calculated lower limit of determination (i.e. the residue which could be identified and measured with confidence) was 0.002mg/kg. Where the residue is quoted in Table 3.2.1.1. to be less than the lower limit of determination, no measurable residue could be detected.

Fenthion persistence in the soil

In March 2005, an experiment was conducted involving a deliberate application of fenthion to tubes containing soil to standardise the results of the residue analysis and to assess its rate of breakdown. A sample of soil from Kotoloname (see section 3.2.2.) was used, from which 5-6g sub-samples were packed into glass tubes. On 14 March 250µl of fenthion was added to each of 20 tubes, 5 of which were immediately closed with lids and deep frozen. The remainder were left in the shade at ambient temperature with their lids off. Next, five more were closed with lids and deep frozen at 24, 39, 101 and 168 hour intervals. Each of the whole soil samples (between 5 and 5.5g) were transferred to a soxhlet thimble. The tube containing the soil was washed with acetone and the rinsings transferred to the extraction flask. The apparatus was then assembled and the samples soxhlet-extracted, with acetone, for four hours. Analysis was then conducted as above for the 2004 soil samples. In addition, a sample of the solution of fenthion used for the experiment was also analysed. 250µl of the fenthion formulation used was transferred, by syringe, to a 25ml volumetric flask and diluted to the mark with acetone (std T1). 5.0ml of this solution was then diluted to 10ml, with acetone (std T2). Calculation of percentage recovery was based on comparison with these two standards.

3.2.1.1.3. RESULTS

Bird Surveys

Two morning surveys and one evening survey were conducted prior to the control and one morning survey completed after the spraying. Thirty-three species (marked with asterisks in Table 3.2.1.2.) in addition to the Red-billed Quelea birds *Q. quelea lathamii* were recorded during the timed bird counts and line transect walks, involving 290 encounters. Because no species were very numerous, the total numbers of birds encountered in each sample were used to analyse the data. The information from the post-spray surveys was compared with the averages of the two pre-spray morning sessions. No important differences were found between the numbers of birds encountered before the spraying with those recorded afterwards in either the timed bird counts or the line transects (Table 3.2.1.1.2); in some cases, the numbers increased after the spraying.

After the spraying, one non-target bird (a male Red-backed Shrike *Lanius collurio*) was found dead and four non-target birds of three species (1 Steppe Buzzard *Buteo vulpinus*, 1 Southern Yellow-billed Hornbill *Tockus flavirostris*, 2 female Greater Whitethroat *Sylvia communis*) were found in a moribund state within the census area. These birds recovered after rest and being provided with water. A Laughing Dove *Streptopelia senegalensis* that allowed a close approach was partly moribund but evaded capture. Remains of another were found suggesting that it had been the victim of a predator.

Cholinesterase levels in birds

Target birds: Sebalola Quelea colony

Table 3.2.1.1.3 summarises results of the cholinesterase studies in which significant depressions of both acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) were demonstrated in the target quelea birds and the differences were highly significant (Table 3.2.1.1.4), there being no overlap between the range of pre-spray and post-spray values for either acetylcholinesterase (AChE) or butyrylcholinesterase (BChE).

There was significant depression of mean cholinesterase levels among both male and female quelea, following exposure to fenthion at Sebalola. When interpreting these results, it should be borne in mind that although pre-spray birds were effectively a random sample captured in mist-nets while they were either entering or leaving the colony, the sample of post-spray birds had all been severely incapacitated as, being unable to fly, they were captured on the ground. Levels of depression of BChE, a more sensitive indicator of acute cholinesterase inhibition by organophosphates in birds, were 18% and 24% greater than for AChE in males and females respectively.

Non-target species: Sebalola Quelea colony

Samples of non-target birds caught after spraying also had markedly reduced levels of both AChE and BChE in comparison with expected pre-spray levels (Table 3.2.1.1.3) but the sample sizes were too small for statistical analyses.

Following colony spraying, cholinesterase samples taken from two nestling Laughing Doves *Streptopelia senegelensis*, being brooded in a nest on the periphery of the sprayed colony did not show any depression in the levels of BChE, which is a better indicator of acute effects resulting from direct exposure. However, AChE levels, a more suitable measure of chronic exposure, were depressed by almost 50% (Table 3.2.1.1.3). This probably reflects the incremental absorption of fenthion by nestlings

still being fed crop milk by their mother, which would have been foraging within the area of the adjacent sprayed colony.

Compared to the cholinesterase levels of an unsprayed Greater Whitethroat *Sylvia communis* both the AChE and BChE of two individuals captured after spraying were markedly depressed, by an average of 70% and 63% respectively. Similarly, although pre-spray samples were not obtained, the Southern Yellow-billed Hornbill *Tockus flavirostris* had very depressed AChE and BChE levels compared with pre-spray adult quelea and other unexposed non-target species (Tables 3.2.1.1.3 & 3.2.1.1.5). The Steppe Buzzard *Buteo vulpinus*, a bird of prey and the largest species in the sample, was in tetanus and unable to fly when caught. Both its AChE and BChE levels were low and within the range found for sprayed quelea. However, after provision of water and time in holding it was able to fly off and perch.

Non-target species: unsprayed birds caught near Gaborone, near Shakawe and at Kotoloname

Cholinesterase levels for adults of other weaver birds (*Ploceus* species) were in a similar range to those found for pre-spray quelea. Surprisingly, values for juveniles were much lower and did not overlap with those of adults for both *P. velatus* and *P. xanthops* (Table 3.1.1.1.5). In contrast, ChE levels of the only sampled juvenile babbler (*Turdoides jardineii*), were higher than all the adult values, and AChE levels of young *Streptopelia senegalensis* were higher than adults (Tables 3.2.1.1.3 & 3.2.1.1.5).

BChE values for unexposed male and female quelea were within the range for most unsprayed non-target species, only values for *Sporopipes squamifrons* being generally lower; and a greater maximum value was recorded for one *P. xanthops*. For AChE, individuals of a few species and all the babblers, *Turdoides jardineii,* had values outside the upper range for unsprayed quelea (Table 3.2.1.1.5).

Observations on other taxa

In addition to effects on birds, an unidentified lizard, blister beetles, millipedes and solifugids were found dead in the area. The lizard was in a track and so may have been killed by the spray vehicle itself rather than the spray. A mass of feathers from a Laughing Dove *S. senegalensis* was found indicative of predation by a bird of prey, perhaps of a pesticide-affected moribund bird. Raptors seen in the colony after the spraying included a Lanner Falcon *Falco biarmicus* and a Gabar Goshawk *Accipiter gabar* which would have been likely to eat pesticide-affected birds. Before the spraying at least one Black Mamba *Dendroaspis polylepis* was shot to protect the team cutting the paths

Fenthion residues in the soil

The soil contamination studies are summarised in Table 3.2.1.1.6. No correction was made for moisture content which was less than 10% in all cases. No measurable amounts of fenthion could be detected in any of the pre-spray soil samples, so all are reported as being residues <0.002 mg/kg. The post-spray results show that the spray deposition was uneven with the highest concentrations (maximum 1.52 mg/kg) clustered at the end of transect two and the beginning of transect three. The lowest concentration was so low (0.002) that it is doubtful if the spray was applied at the sampled sites (at the beginning of transect 1 and in transect 4).

The results of the deliberate contamination experiment revealed almost 90% recovery of the concentration of pesticide deposited after 24 hours, decaying to only

45% after 168 hours (Table 3.2.1.1.7) in an almost linear rather than the expected exponential manner (Figure 3.2.1.1.2.).

3.2.1.1.4. DISCUSSION

No effects of the spraying on non-target birds were detectable by the results of the bird censuses, although post-spray sampling was curtailed. However, there had clearly been some adverse effects since one dead and five moribund non-target birds were found the day after the spraying. Furthermore all of the moribund birds and the nestling doves had reduced ChE levels indicative of fenthion poisoning. In man, depression of cholinesterase to <50% normal indicates possible pesticide poisoning requiring removal from exposure and / or treatment with anticholinergic drugs such as atropine and pralidoxime (Coye *et al.* 1986). Laboratory studies on birds suggest that cholinesterase activity of less than two standard deviations (about 20%) below the control mean is indicative of exposure to anti-cholinesterases such as organophosphates (Ludke *et al.* 1975 cited in Grue *et al.* 1991). Therefore, the high percentage depression (64 to 88%) found among quelea and similarly depressed or low ChE values of the non-target species from the sprayed colony confirm the utility of this assay for assessing fenthion poisoning. However, inter-specific variation and even differences in ChE levels between between adults and young emphasise the importance of obtaining baseline data.

Although the birds that had been affected recovered after drinking and rest, organophosphate poisoning may have longer-term effects on the birds' behaviour and ecology, reducing foraging efficiency or increasing vulnerability to predators for instance. There is evidence of behavioural and population-level effects on White-throated Sparrows *Zonotrichia albicollis* sprayed with the organophosphate fenitrothion used against Spruce Budworm moths *Choristoneura fumiferana* in Canada (Busby *et al.* 1990). This control resulted in a 75% decline in the reproductive success of *Z. albicolis* in the sprayed area. Inhibited acetylcholinesterase can reactivate slowly and may depend on production of new enzyme (Walker 2003). It is also possible that targets additional to the acetylcholinesterase may be affected by organophosphates (Richards *et al*. 1999) and this has led to concern that birds (as well as affected sheep farmers and gulf war veterans) may be experiencing long term neurological and behavioural effects attributable to factors other than acetylcholinesterase inhibition (Walker 2003).

The fenthion residues detected in the soil after spraying were unsurprisingly much higher than the pre-control trace levels. However, only the maximum value (1.52 mg/kg) was as high as the levels (approx. 1 to >3 mg/kg) recorded immediately after application by van der Walt (2000) and as high as his maximum (1.5 mg/kg) at 8 days after spraying. Nevertheless the spray deposition was uneven, suggesting that either spray from the machines was emerging at varying rates indicative of poorly maintained apparatus (e.g. with partially blocked nozzles) or operator errors such as allowing the vehicle to stop or be driven at varying speeds. In either case, closer attention to correct spraying procedures is indicated. The results of the fenthion persistence study suggest that about 0.7 mg/kg could have remained at the most contaminated sample site after one week. Consideration should be given to removing the quelea carcasses after spraying and disposing of them safely. This is a legal requirement in South Africa.

It was of interest that of the five affected species of non-target birds, three (Steppe Buzzard, Red-backed Shrike, Greater Whitethroat) are intercontinental migrants that move back and forth between the Palaearctic and Afro-tropical regions. Migrating

birds may be more stressed and thus more susceptible to poison than resident species, a possibility that requires further investigation.

Table 3.2.1.1.1. Vertebrate species recorded inside or within 1 km of the Quelea colony at Sebalola. The sequence and nomenclature follows Sinclair & Ryan (2003) for the birds and Kingdon (1997) for mammals. Bird species marked with an asterisk were recorded within the colony during the timed bird count or line transect surveys.

Mammals
Aardvark *Orycteropus afer,* Bush Duiker *Sylvicapra grimmia,* Scrub Hare *Lepus saxatalis,* Spring Hare *Pedetes capensis.*

Birds
White Stork *Ciconia ciconia,* Yellow-billed Kite *Milvus aegyptius,* White-backed Vulture *Gyps africanus,* Cape Vulture *Gyps coprotheres,* Brown Snake Eagle *Circaetus cinereus,* Bat Hawk *Macheiramphus alcinus,* Lizard Buzzard *Kaupifalco monogrammicus,* Gabar Goshawk *Melierax gabar*,* Steppe Buzzard *Buteo vulpinus,* Tawny Eagle *Aquila rapax,* Ayre's Hawk Eagle *Aquila ayresii,* Lanner Falcon *Falco biarmicus,* Peregrine Falcon *Falco peregrinus,* Natal Spurfowl *Pternistes natalensis*,*Crested Francolin *Dendroperdix sephaena,* Swainson's Spurfowl *Pternistes swainsonii*,* Kurrichane Buttonquail *Turnix sylvaticus*,* Spotted Thick-knee *Burhinus capensis,* Crowned Lapwing *Vanellus coronatus,* Speckled Pigeon *Columba guinea*,* Cape Turtle dove *Streptopelia capicola*,* Laughing Dove *Streptopelia senegalensis*,* Emerald-spotted Wood Dove *Turtur chalcospilos,* Grey Go-Away Bird *Corythaixoides concolor*,* Diderick Cuckoo *Chrysococcyx caprius* *, Levaillant's Cuckoo *Clamator levaillantii,* Senegal Coucal *Centropus senegalensis*, Barn Owl *Tyto alba,* Verreaux's Eagle-Owl *Bubo lacteus,* Spotted Eagle-Owl *Bubo africanus*,* African Scops-Owl *Otus senegalensis,* Fiery-necked Nightjar *Caprimulgus pectoralis,* Square-tailed Nightjar *Caprimulgus fossii,* Red-faced Mousebird *Urocolius indicus,* African Hoopoe *Upupa Africana,* European Bee-eater *Merops apiaster,* Southern Yellow-billed Hornbill *Tockus leucomelas*,* African Grey Hornbill *Tockus nasutus*,* Barn swallow *Hirundo rustica*,* Fork-tailed Drongo *Dicrurus adsimilis*,* Pied Crow *Corvus albus,* Arrow-marked Babbler *Turdoides jardineii*,* Dark-capped Bulbul *Pycnonotus tricolour,* African Red-eyed Bulbul *Pycnonotus nigricans*,* Kurrichane Thrush *Turdus libonyanus*,* White-throated Robin-Chat *Cossypha humeralis*,* Thrush Nightingale *Luscinia luscinia*,* Kalahari Scrub Robin *Cercotrichas paena*,* White-browed Scrub Robin *Cercotrichas leucophrys*,* Greater Whitethroat *Sylvia communis,* Chestnut-vented Tit-babbler *Parisoma subcaeruleum*,* Bar-thoated Apalis *Apalis thoracica*,* Tinkling Cisticola *Cisticola rufilatus,* Tawny-flanked Prinia *Prinia subflava,* Grey-backed Camaroptera *Camaroptera brevicaudata*,* Chinspot Batis *Batis molitor*,* Red-backed Shrike *Lanius collurio*,* Brown-crowned Tchagra *Tchagra australis*,* Bru-bru *Nilaus afer*,* Crimson-breasted Bush Shrike *Laniarius atrococcineus*,* Tropical Boubou *Laniarius aethiopicus*,* Orange-breasted Bush shrike *Telophorus sulfureopectus,* Grey-headed Bush shrike *Malaconotus blanchoti*,* Cape Glossy Starling *Lamprotornis nitens,* Southern Grey-headed Sparrow *Passer diffuses,* Yellow-throated Petronia *Petronius superciliarius,* Red-billed Buffalo-Weaver *Bubalornis niger*,* Southern Masked Weaver *Ploceus velatus,* Red-billed Quelea *Quelea quelea lathamii*,* Green-winged Pytilia *Pytilia melba,* Blue waxbill *Uraeginthus angolensis,* Eastern Paradise-whydah *Vidua paradisea.*

Reptiles
Black Mamba *Dendroaspis polylepis,* unidentified lizards *Lacerta* sp.

Amphibia
Banded Rubber Frog *Phrynomantis bifasciatus,* Ornate Frog *Hildebrandtia ornate.*

Table 3.2.1.1.2. Numbers of birds encountered during the timed bird counts and line transect surveys.

Timed Bird Counts (a.m.)

Site	Pre-spray			Post-spray
			Averag	
	No. of Birds			No of Birds
Date	1.03.04	2.03.04		4.03.04
1	5	6	5.5	9
2	5	5	5	5
3	7	5	6	6
4	11	9	10	12
5	-	11	11	10

Transects (a.m.)

Site	Pre-spray			Post-spray
Date	1.03.04	2.03.04		4.03.04
			Averag	
	No. of Birds			No of Birds
1	5	6	5.5	6
2	5	6	5.5	7
3	8	11	9.5	6
4	10	15	12.5	9
5	-	12	12	13

Table 3.2.1.1.3. Comparison of Cholinesterase values at Unsprayed and Sprayed Sites.

Treatment	Species	Sex/Age	x Q AChE U/g (range)	n	x BChE U/g (range)	n
Pre-spray	*Quelea quelea*	M/Adult	**1.9** (1.6 - 2.4)	10	**1.48** (1.18 - 2.51)	9
Post-spray	" "	M/Adult	**0.6** (0.2 - 1.0)	14	**0.18** (0.10 - 0.23)	14
		% depression	**70**		**88**	
Pre-spray	*Quelea quelea*	F/Adult	**2.0** (1.2 - 3.6)	10	**1.29** (0.88 - 1.92)	10
Post-spray	" "	F/Adult	**0.7** (0.4 - 1.1)	5	**0.15** (0.09 - 0.20)	5
		% depression	**64**		**88**	
Pre-spray	*Streptopelia senegalensis*	Pullus	**14.8** (13.3 - 16.2)	2	**1.26** (1.19 - 1.32)	2
Post-spray	" "	Pullus	**7.6** (6.9 - 8.3)	2	**1.35** (1.34 - 1.35)	2
		% depression	**48**		**-7**	
Unsprayed	*Sylvia communis*	F/Adult	**2.5**	1	**1.23**	1
Post-spray	" "	F/Adult	**0.8** (0.7 - 0.8)	2	**0.46** (0.30 -0.61)	2
		% depression	**70**		**63**	
Post-spray	*Tockus flavirostris*	Adult	**0.4**	1	**0.12**	1
Post-spray	*Buteo buteo vulpinus*	Adult	**1.1**	1	**0.23**	1

M = Male, F = Female, Juv = Juvenile

Table 3.2.1.1.4. Comparison of Pre-spray and Post-spray Cholinesterase values for *Quelea quelea lathamii*. One-tailed t-tests assuming unequal variances.

Sex	**Cholinesterase**	**t**	**P**
Male	AChE	12.58	<0.001
	BChE	7.99	<0.001
Female	AChE	5.41	<0.001
	BChE	9.25	<0.001

Table 3.2.1.1.5. Cholinesterase values at unsprayed sites. Sequence and names of birds follow Sinclair & Ryan (2003). M = Male, F = Female, Juv = Juvenile.

Species		**Sex/Age**	**Q AChE U/g (range)**	**n**	**BChE U/g (range)**	**n**
Vernacular name	**Scientific name**					
Columbidae						
Red-eyed Dove	*Streptopelia semitorquata*	Adult	**3.5** (2.8 - 4.2)	2	**1.45** (1.04 - 1.85)	2
Cape Turtle Dove	*Streptopelia capicola*	Adult	**2.2**	1	**0.48**	1
Laughing Dove	*Streptopelia senegalensis*	M/Adult	**4.0** (3.6 - 4.4)	2	**1.51** (1.32 - 1.70)	2
Laughing Dove	*Streptopelia senegalensis*	F/Adult	**6.6**	1	**2.48**	1
Emerald-spotted Wood-Dove	*Turtur chalcospilos*	Adult	**3.7**	1	**0.79**	1
Halcyonidae						
Pygmy Kingfisher	*Ispidina picta*	Adult	**4.8**	1		
Woodland Kingfisher	*Halcyon senegalensis*	Adult	**1.2** (1.0 - 1.4)	2	**1.26** (1.14 - 1.38)	2
Timaliidae						
Arrow-marked Babbler	*Turdoides jardineii*	Adult	**4.8** (3.8 - 5.9)	3	**1.47** (1.25 - 1.75)	3
Arrow-marked Babbler	*Turdoides jardineii*	Juv.	**7.7**	1	**2.33**	1
Pycnonotidae						
African Red-eyed Bulbul	*Pycnonotus nigricans*	Adult	**1.9** (1.1 - 2.5)	3	**0.89** (0.84 - 0.94)	2
Turdidae						
Kurrichane Thrush	*Turdus libonyanus*	Juv.			**2.03**	1
White-browed Robin-Chat	*Cossypha heuglini*	Adult	**1.7**	1	**1.42**	1
White-browed Scrub-Robin	*Cercotrichas leucophrys*	Adult	**3.6**	1		
White-browed Scrub-Robin	*Cercotrichas leucophrys*	Juv.	**1.6**	1	**2.15**	1
Sylviidae						
Chesnut-vented Tit-Babbler	*Parisoma subcaeruleum*	Adult			**1.64**	1
Rattling Cisticola	*Cisticola chiniana*	Juv.	**3.4**	1	**1.67**	1
Yellow-bellied Eremomela	*Eremomela icteropygialis*	Adult	**2.2**	1	**1.95**	1
Grey-backed Camaroptera	*Camaroptera brevicaudata*	Adult	**5.7**	1	**1.88**	1
Muscicapidae						
Marico Flycatcher	*Bradornis mariquensis*	Adult	**2.3** (2.2 - 2.3)	2	**1.26** (1.24 - 1.28)	2
Grey Tit-Flycatcher	*Myioparus plumbeus*	Adult	**2.3**	1	**1.74**	1
Laniidae						
Red-backed Shrike	*Lanius collurio*	F/Adult	**2.9**	1	**1.74**	1
Crimson-breasted Shrike	*Laniarius atrococcineus*	Adult	**1.9**	1	**1.55**	1
Sturnidae						
Cape Glossy Starling	*Lamprotornis nitens*	Adult	**1.1**	1	**0.93**	1
Ploceidae						

Southern Grey-headed Sparrow	*Passer diffusus*	Ad.+Juv.	**3.1** (2.2 - 4.4)	8	**1.28** (0.87 - 1.86)	8
Cape Sparrow	*Passer melanurus*	M/Adult	**3.4** (2.7 - 4.0)	2	**1.54** (1.00 - 2.07)	2
Scaly-feathered Finch	*Sporopipes squamifrons*	Adult	**1.3** (1.1 - 1.6)	12	**0.50** (0.28 - 0.92)	11
Golden Weaver	*Ploceus xanthops*	Adult	**2.3** (1.9 - 2.6)	5	**2.86** (2.22 - 3.39)	5
Golden Weaver	*Ploceus xanthops*	Juv	**1.6** (1.5 - 1.6)	2	**1.63** (1.60 - 1.66)	2
Southern Masked Weaver	*Ploceus velatus*	Adult	**2.1** (1.1 - 3.2)	3	**2.42** (2.38 - 2.45)	2
Southern Masked Weaver	*Ploceus velatus*	Juv	**0.7** (0.4 - 0.9)	2	**0.98** (0.90 - 1.06)	2
Lesser Masked Weaver	*Ploceus intermedius*	Adult	**1.8** (1.4 - 2.3)	5	**1.70** (0.89 - 2.80)	5
Estrildidae						
Green-winged Pytilia	*Pytilia melba*	M/Adult	**1.5** (1.4 - 1.5)	3	**0.84** (0.61 - 1.00)	3
Green-winged Pytilia	*Pytilia melba*	F/Adult	**2.1**	1	**1.13**	1
Blue Waxbill	*Uraeginthus angolensis*	F/Adult	**2.2** (2.1 - 2.2)	2	**0.90** (0.84 - 0.95)	2

Table 3.2.1.1.6. Residues of fenthion (mg/kg) in soil samples collected at Sebalola before (1 March 2004) and after (4 March 2004) spraying. The code numbers refer to four samples collected at each of the sites where the timed bird counts were made before the starting positions of each transect (T1 = transect 1; see Fig. 3.2.1.1.1).

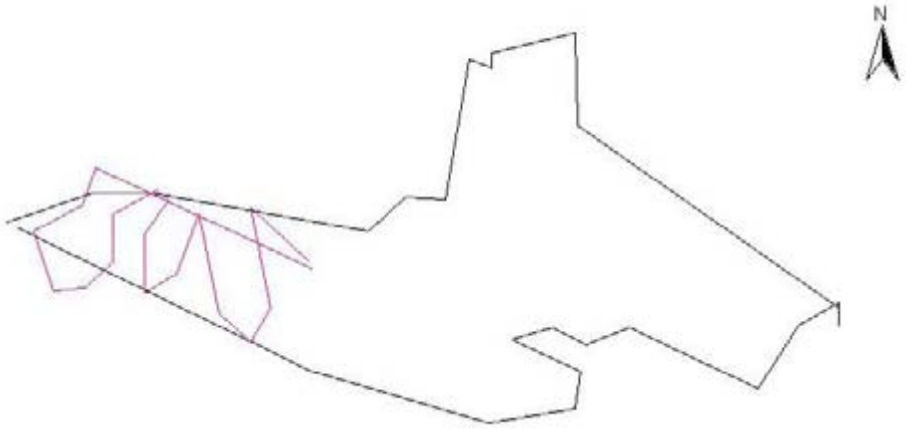
Site	**Pre – spray**	**Post - spray**
T1-1	<0.002	<0.002
T1-2	<0.002	0.004
T1-3	<0.002	0.03
T1-4	<0.002	0.02
T2-1	<0.002	0.003
T2-2	<0.002	0.007
T2-3	<0.002	0.006
T2-4	<0.002	0.34
T3-1	<0.002	0.16
T3-2	<0.002	1.52
T3-3	<0.002	0.03
T3-4	<0.002	0.01
T4-1	<0.002	0.005
T4-2	<0.002	0.006
T4-3	<0.002	0.002
T4-4	<0.002	0.02
T5-1	<0.002	0.02
T5-2	<0.002	0.15
T5-3	<0.002	0.008
T5-4	<0.002	0.03

Table 3.2.1.1.7. Results of the Fenthion Persistence Study.

Exposure period	Tube	Lab Code	Percentage recovery of added fenthion	
24 Hours	1	1/05	93.6	Range: 70.5 – 96.4
24 Hours	2	2/05	91.0	Mean: 88.3%
24 Hours	3	3/05	89.9	
24 Hours	4	4/05	70.5	
24 Hours	5	5/05	96.4	
39 Hours	6	6/05	110.8	Range: 38.3 – 110.8
39 Hours	7	7/05	101.0	Mean: 84.1%
39 Hours	8	8/05	59.5	
39 Hours	9	9/05	110.8	
39 Hours	10	10/05	38.3	
101 Hours	11	11/05	62.5	Range: 45.6 – 62.5
101 Hours	12	12/05	53.6	Mean: 54.9%
101 Hours	13	13/05	54.3	
101 Hours	14	14/05	58.5	
101 Hours	15	15/05	45.6	
168 Hours	16	16/05	37.2	Range: 37.2 – 54.9
168 Hours	17	17/05	37.9	Mean: 45.0%
168 Hours	18	18/05	54.9	
168 Hours	19	19/05	50.1	
168 Hours	20	20/05	44.8	

Figure 3.2.1.1.1. Diagrams of the quelea colony and the layout of the transects within it. (A). The shape of the colony with the positions of the transects at its western edge. (B). A detailed view of the route of the transect walk. TBC = Timed Bird Count; T1S = start of transect 1; T1F = finishing point of transect 1. Soil samples were taken at the TBC positions.

A



B

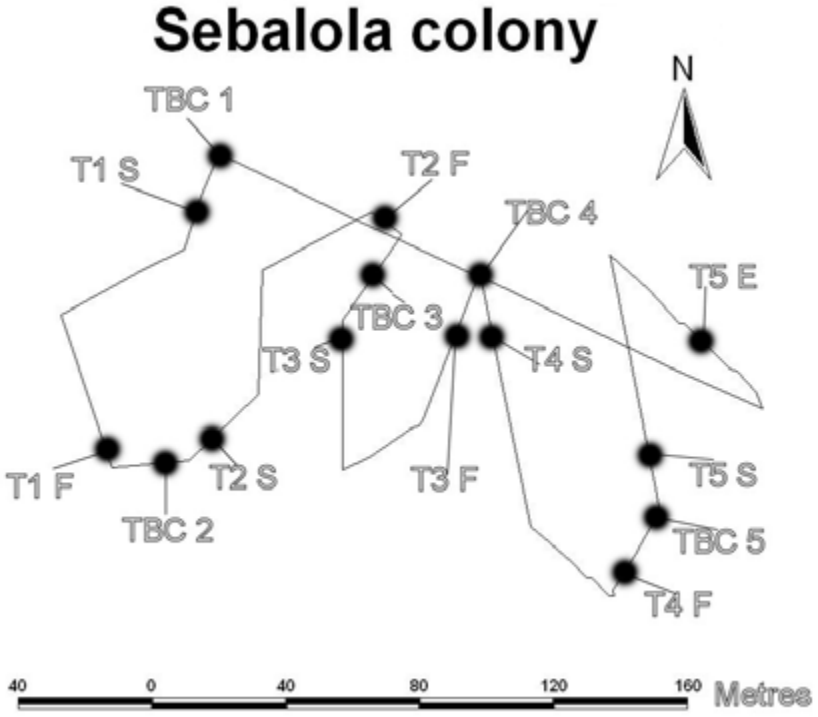
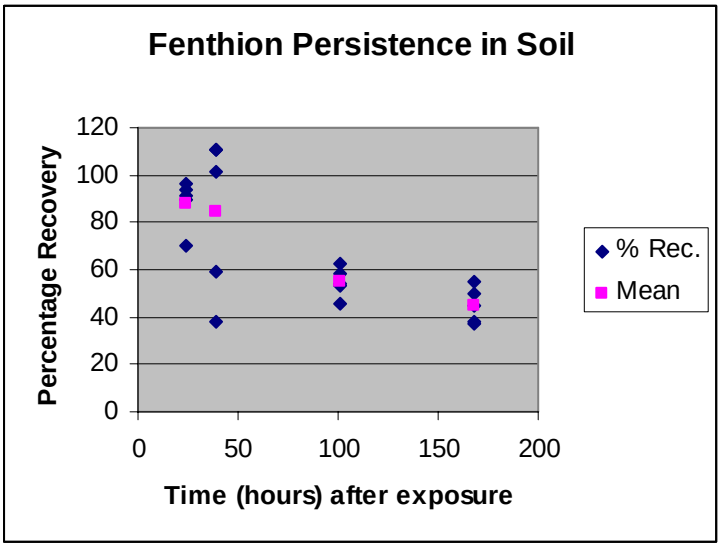


Figure 3.2.1.1.2. The decay of fenthion in soil. Results of the persistence experiment.



3.2.1.2. *Data on environmental effects of quelea control obtained during field work in Botswana. Effects of a firebomb explosion*

3.2.1.2.1. INTRODUCTION

An opportunity arose in March 2005 to study the effects of the control of quelea using explosives. Although it had been hoped to study further spraying events this proved to be impossible as no breeding colonies were reported in Botswana during the scheduled visit in February – March 2005. However a roost was found near Kotoloname at 24°28'20'S, 25°16'33"E in the Molepolole (24°25'S, 25°32'E) area. It was initially expected that the roost would be controlled with fenthion hence blood samples from non-target birds caught in mist-nets were taken for acetylcholinesterase assays (see section 3.2.1.1. above).

3.2.1.2.2. STUDY SITE AND METHODS

Study Site

The quelea birds were attacking crops within the vicinity of the roost, principally sorghum. A random sample of 30 sorghum heads along a transect in a field revealed 54% damage on 11 March; 11 of the heads had no grains left on them at all. The birds were roosting in thick *Acacia mellifera* bush in a 151 x 52m strip that was surrounded by open grassland. Beyond the roost there was a marshy area with some standing water where the birds came to drink. Estimates of the density of *A. mellifera* plants in 6 random 20 x 20m quadrats ranged from 23 to 88 (mean 54.7) and in 4 randomly selected quadrats the density of *Dicrostachys cinerea* ranged from 6 to 19 plants (mean 13.4). Percentage cover with *A. mellifera* from 8 random samples of 20 x 20m quadrats gave percentages of 1, 5, 20, 20, 70, 75, 80, and 90 (mean 45.1%). Other species present included *Acacia erioloba, Acacia hebellada, Acacia tortilis, Aloe zebrina, Boscia albitrunca, Cadaba aphylla, Combretum hereroense, Croton gratissimus, Grewia flava, Rhus pyroides, Ximenia caffra* and *Ziziphus mucronata,*.

Methods

Bird Surveys

A combination of line transects and point counts for fixed times was used (Bibby *et al.* 1992), as described for the fenthion study above (see section 3.2.1.1.). Six sites for timed bird counts were chosen along a route, interspersed with 100m long transects. The first transect began 40m from the first timed bird count site and there were also 40m gaps between the finish and start points of each of the five successive transects, with a timed bird count made at the centre of the gaps.

Soil samples

Pre-and post-control samples of soil were taken for subsequent analyses. Eleven pre-control samples were collected at 20m intervals along a transect across the roost area on 10 March 2005. After the explosive control, samples were taken between 1000 and 1200 on 18 March, in relation to craters created by the explosions along a transect within the roost area. At each selected crater a sample was taken from its centre and from soil 10m distance from it to the left and to the right, perpendicular to the transect line, providing three samples for each of the 10 craters selected. The samples of approximately uniform volumes (approximately 200g, maximum depth 10cm) were taken using trowels (washed with distilled water after each sampling) and stored in cloth bags. They were then air-dried, sieved and any vegetable material present was removed prior to the samples being double-wrapped in aluminium foil and sealed within polythene bags. All layers were labelled with the sample details before shipment to the UK, where they were placed in a deep freeze (-18 °C) pending analysis, which commenced in May 2005. Analytical procedures followed the methods described in 3.2.1.1. After de-frosting the soil samples and allowing them to warm to room temperature, each sample was thoroughly mixed and a 50g sub–sample removed, placed into a cellulose extraction thimble (Whatman)

and extracted in a soxhlet apparatus, with acetone, for four hours. Each extract was then evaporated to a volume of 5 – 10ml using a rotary vacuum evaporator at 40^0C and quantitatively transferred to a 20 or 25ml volumetric flask, with acetone, and the volume adjusted to the mark. All extracts were stored in a refrigerator at < 4^0C pending analysis by FID using an HP 6890 Instrument, with Model HP7683 autosampler. Data collection and handling was completed using Ezichrom Elite data handling software (v3). Column: Capillary, 30m CPSil5, 0.25mm i.d., 0.25µm film thickness; *Oven programme*:1 2; Oven temp. (°C):100 250; Iso time (min): 15.0; Ramp rate (°C/min): 10; *Detector*: Temp. 250°C; Hydrogen: 30ml/min Air: 400ml/mi ; Injector temp. 200°C; Purge Flow: 50 ml/min; Total flow: 52.6ml/min; Purge Time: 0.75 minutes; Mode: Splitless; Carrier gas flow rate: 2.6 ml/min; Injection volume: 0.2µl (automatic sample injection); Data collection time: 30.00 min; Retention time:8 – 28 mins. Estimation of diesel oil components was made using a commercially obtained C16 reference solution.

Carcass searches

Twelve hours after the explosion, six people walked through the affected zone in parallel lines, but separated by approximately 10 m, collecting and recording any dead or moribund non-target organisms.

Explosion

Three hectares were subjected to the explosion. Explosive mixtures (approx. 1-2 litres of petrol and 1-2 litres of diesel (average about 1.5l of each in a 50:50 mixture) totalling of 800 litres were used) were placed in 5 litre white opaque plastic containers at the base of *Acacia mellifera* bushes that had evidence of quelea having roosted in them recently (fresh droppings on the branches). The addition of diesel keeps the flame alight longer than petrol alone, but also gives rise to smoke. Under each of the 233 plastic containers that were deployed was placed a 150g Trojan C150 Cast booster (38 x 120mm of pentolite, a mixture of TNT and RDX, encased in yellow plastic, manufactured by Ensign-Bickford, South Africa, pty, Ltd). Each booster had a hole drilled in the middle, through which red detonating cord (plastic cord, 8 g/m, Auxim Tech. Ltd., China) was fed. At the ignition site at the beginning of the cord (total length 1050m) was about 120cm of yellow safety fuse of slow-burning (8-10mm.s^{-1}) gun powder, giving approximately two and a half minutes between ignition and detonation. This was connected to an electric detonator cord containing a white powdered high explosive core to set off the detonator. This created a shock wave to the detonating cord, along which it travels at 6000m.s^{-1}, exploding each booster as it travels. The blast was tape-recorded and a sonogram of it created using AVISOFT software.

3.2.1.2.3. RESULTS

Explosion

The air temperature at 1845 on 17 March 2005 was 24°C, relative humidity was 59% and the wind was negligible, before the explosives were detonated at 1935. A sonogram of the blast is given in Fig. 3.2.1.2.1. From this it can be seen that the sound wave consists of a series of discrete episodes, perhaps representing the sound waves from successive explosions of each of the 233 containers as the detonation travelled along the cord.

Carcass searches

Four dead mammals (1 Namaqua Rock mouse *Aethomys namaquensis* and 3 Bushveld Gerbils *Tatera leucogaster*) and 3 dead birds (1 Lesser Grey Shrike *Lanius minor*, 1 Marico Sunbird *Cinnyris mariquensis* and 1 Rattling Cisticola *Cisticola chiniana*) were found. In addition dead caterpillars, grasshoppers (*Zonocerus* sp. and ?*Nomadacris* sp.) and millipedes were found dead.

Vertebrate Surveys

The species of birds, mammals and reptiles recorded within 2km of the study site are given in Tables 3.2.1.2.1., 3.2.1.2.2. and 3.2.1.2.3. respectively. The numbers of species of birds and the numbers of individual birds recorded during the timed bird counts and transects conducted before and after the explosion are presented in table 3.2.1.2.4. The differences between the pre- and post-control results were not significant (Wilcoxon Signed Rank test, $P > 0.075$).

Soil samples

Diesel and plastic residues were detectable in the soil samples. The characteristic chromatographic pattern of diesel oil, observed on FID analysis, was confirmed by Gas Chromatography – Mass Spectrometry as C12 – C28 hydrocarbons as expected in diesel fuel. The relative concentrations of each hydrocarbon varies from those available in reference texts but this can be explained by variation in the source of the diesel and its purity and by possible increased volatilisation of some hydrocarbon fractions. Fig. 3.2.1.2.2. gives the GLC trace from a pre-explosion samples and Fig. 3.2.1.2.3. from a post-explosion sample. Table 3.2.1.2.5. gives details of the concentrations recorded before the explosion (mean 0.077 mg/kg; S.D. 0.036), in the craters (mean 4.436, S.D. 2.828), 10m to the left of craters (mean 0.556, S.D. 0.915) and 10m to the right of craters (mean 0.242, S.D. 0.065). The concentrations on either side of the craters were not significantly different ($P>0.3$, two tailed t test, assuming unequal variances) but the combined data were significantly lower than those in the craters ($P = 0.001$). The latter were also very significantly greater than the pre-control data ($P =0.0009$).

Residues of dibutyl phthalate were also detected in some post–explosion samples (but not in any pre-explosion samples) with identity being confirmed by GC-MS. Quantification of these residues was not attempted. The origin of these residues is likely to be from the plastic containers holding the diesel fuel.

Miscellaneous Impacts

Most of the *A. mellifera* bushes that had been within the explosion area were blackened. In some cases the whole plant was affected in others only the lower stems and branches. It is anticipated that all of these plants will recover.

Many of the plastic containers were incompletely burnt leaving pieces of white plastic scattered on bushes and on the ground, together with a few red plastic rings from the lids of the containers.

At the site where the diesel and petrol mixtures were poured into the containers there was a substantial amount of spillage, leaving a patch of oil about 1m in circumference.

Before and after the control, staff involved with the explosion operation were seen collecting berries of *Grewia* spp. to eat, roots of *Aloe zebrina* for later brewing into beer (“kaadi”) and the roots of a plant locally known as ngamane that are used to treat kidney disease and high blood pressure. There were also reports of the collection of combs from subterranean wasp nests, presumably for honey. There was also some litter left behind by the control team such as empty drinks cans.

Although warnings had been issued with a loudspeaker van and the local populace were informed of the imminent explosion such that livestock had been removed from the scene, the procedures had not been completely successful as two donkeys were present within 300m of the explosion at the time of ignition. They had walked into the area after dusk and were only detected just before the explosion by their braying.

DISCUSSION

The explosion was not without environmental impacts. At least seven non-target vertebrates were killed and the vegetation was damaged, but not killed. There were also minor impacts as a result of the control team's activities but of greatest concern was the contamination resulting from the explosion itself. Remains of unburnt plastic from incompletely incinerated containers littered the site and these items may take as long as ten years to decompose. There were also residues of the plastic detectable in the soil at the crater sites. The contamination with unburnt diesel and petrol was also substantial with up to 9.31 mg/kg present in one crater. Even 10m to either side of the craters the residues were significantly greater than the pre-explosion background levels, reaching as high as 3.12 mg/kg. The effects of diesel on the soil environment are poorly documented but it is known that its effects on plants vary from species to species and even between subspecies. Diesel can delay seed emergence and reduce percentage germination. The volatile fraction of diesel fuel has been implicated in these processes, with the remaining fraction of diesel fuel in the soil further inhibiting germination by physically impeding water and oxygen transfer between the seed and the surrounding soil environment (Adam and Duncan 2002). Seed germination and growth of soya beans and ryegrass were inhibited by a diesel fuel spill of 2.3 ml/m^2 (Wang & Bartha 1990). Further studies and literature searches are required to establish the potential effects of the levels of contamination detected but given that 800 litres of fuel were exploded in a 3 ha site, if explosions are used regularly or at the same site in successive years, the environmental damage could be severe.

The plastic debris should be collected after explosions and the minor damage by the team involving up-rooting plants and leaving litter could be avoided. In South Africa it is a legal requirement that quelea corpses are removed after control operations. If that policy was adopted throughout the SADC region, it would be simple to ensure that plastic and other debris was removed too at the same time as the quelea carcasses. In South Africa and elsewhere, metal oil drums are used as containers for the fuel mixes instead of plastic. It would be instructive to examine which method presents the least environmental impact.

On the basis of only two studies it is difficult to assess which of control with sprays or using explosions is least damaging to the environment. In terms of numbers of non-target vertebrates killed, both techniques had similar effects (2.3 vertebrates killed per ha in the explosion and 1 killed and 4 severely affected in the spraying operation). No evidence of declines in non-target birds were detected in the censuses after each control method, although the duration of monitoring was restricted. Spraying certainly affects birds deleteriously although the acetylcholinesterase depression may be only a short-term phenomenon. Both techniques lead to soil contamination, with the plastic and diesel residues in the aftermath of the explosions being potentially much longer-lasting and therefore more insidious than the organophosphorus residues.

Table 3.2.1.2.1. Species of birds recorded within a 2km radius of the area used by *Quelea quelea* to roost. Those marked with an asterisk were recorded within the roost area itself.

Abdim's Stork *Ciconia abdimii*, White Stork *Ciconia ciconia*, Yellow-billed Duck *Anas undulata*, Black-shouldered Kite *Elanus caeruleus*,* Yellow-billed Kite *Milvus aegyptius,* Lappet-faced Vulture *Torgos tracheliotus*, White-backed Vulture *Gyps africanus*, Montagu's Harrier *Circus pygargus**, Gabar Goshawk *Melierax gabar**, Steppe Eagle *Aquila nipalensis*,Tawny Eagle *Aquila rapax**, Wahlberg's Eagle *Aquila wahlbergi**, Rock Kestrel *Falco rupicolus**, Secretarybird *Sagittarius serpentarius*, Helmeted Guineafowl *Numida meleagris*, Coqui Francolin *Peliperdix coqui**, Natal Spurfowl *Pternistes natalensis**, Swainson's Spurfowl *Pternistes swainsonii**, Harlequin Quail *Coturnix delegorguei*, Kurrichane Buttonquail *Turnix sylvaticus**, Kori bustard *Ardeotis kori*, Northern Black Korhaan *Eupodotis afraoides*, Double-banded courser *Rhinoptilus africanus**, Bronze-winged Courser *Rhinoptilus chalcopterus*, Namaqua Sandgrouse *Pterocles namaqua**, Cape Turtle Dove *Streptopelia capicola**, Laughing Dove *Streptopelia senegalensis**, Emerald-spotted Wood-Dove *Turtur chalcospilus**, Namaqua Dove *Oena capensis**, Grey Go-Away-Bird *Corythaixoides concolor**, Barn Owl *Tyto alba*, Spotted Eagle-owl *Bubo capensis*, Red-faced Mousebirds *Urocolius indicus* European Bee-eater *Merops apiaster**, African Grey Hornbill *Tockus nasutus* *, Acacia Pied Barbet *Tricholaema leucomelas**, Sabota Lark *Calendulauda sabota*, Rufous-naped Lark *Mirafra Africana**, Grey-backed Sparrowlark *Eremopterix verticaliss**, Barn swallow *Hirundo rustica**, House Martin *Delichon urbica**, Cape Crow *Corvus capensis**, Pied Crow *Corvus albus**, Ashy Tit *Parus cineirascens**, Arrow-marked Babbler *Turdoides jardineii**, Southern Pied Babbler *Turdoides bicolor*, African Red-eyed Bulbul *Pycnonotus nigricans**, Kalahari Scrub-Robin *Cercotrichas paean**, Southern Ant-eating Chat *Myrmecocichla formicivora**, Greater Whitethroat *Sylvia communis**, Chesnut-vented Tit-babbler *Parisoma subcaeruleum**, Zitting Cisticola *Cisticola juncidis*, Rattling Cisticola *Cisticola chiniana**, Tawny-flanked Prinia *Prinia subflava**, Black-chested Prinia *Prinia flavicans**, Yellow-bellied Eremomela *Eremomela icteropygialis**, Long-billed Crombec *Sylvietta rufescens**, Grey-backed Camaroptera *Camaroptera brevicaudata**, Marico Flycatcher *Bradornis mariquensis**, Pririt Batis *Batis pririt**, Red-backed Shrike *Lanius collurio**, Lesser Grey Shrike *Lanius minor**, Brown-crowned Tchagra *Tchagra australis**, Crimson-breasted Shrike *Laniarius atrococcineus**, Southern White-crowned Shrike *Eurocephalus anguitimens*, Cape Glossy Starling *Lamprotornis nitens**, Wattled Starling *Creatophora cinerea**, Marico Sunbird *Cinnyris mariquensis**, Scaly-feathered Finch *Sporopipes squamifrons**, Lesser Masked Weaver *Ploceus intermedius**, Green-winged Pytilia *Pytilia melba**, African Quailfinch *Ortygospiza atricollis*, Shaft-tailed Whydah *Vidua regia**, Yellow Canary *Serinus flaviventris**.

Table 3.2.1.2.2. List of mammal species recorded within a 2km radius of the roost site.

Scrub hare *Lepus saxatilis*, South African Ground squirrel *Geosciurus inauris*, Namaqua rock mouse *Aethomys namaquensis*, Bushveld gerbils *Tatera leucogaster,* Cape fox *Vulpes chama*, Dwarf mongoose *Helogale parvula,* Common genet *Genetta genetta*, Aardvark *Orycteropus afer*, Common warthog *Phacochoerus aethiopicus*, Bush duiker *Sylvicapra grimmia*.

Table 3.2.1.2.3. List of reptile species recorded within a 2km radius of the roost site. Mozambique Spitting Cobra *Naja mossambica*, Southern African Rock Python *Python sebae natalensis*

Table 3.2.1.2.4.

Table.	Numbers of species and numbers of individual birds recorded at (a) six sites where timed bird counts (TBCs) were									
made and (b) along five transects between the TBCs before and after the explosion. Two replicates were conducted before the										
explosion of samples taken in the morning.										
		PRE		PRE		PRE	AVERAGES		POST-EXPLOSION	
		No of Spp.	No of Birds	No of Spp.	No of Birds	No of Spp.	No of Birds		No of Spp.	No of Birds
TBC1	am	7	44	9	21	8	32.5		7	20
TBC1	pm	7	23			7	23		3	10
Transect1	am	8	18	7	8	7.5	13		4	4
Transect1	pm	8	14			8	14		4	11
TBC2	am	8	19	4	5	6	12		8	12
TBC2	pm	11	18			11	18		6	10
Transect2	am	9	21	6	16	7.5	18.5		7	19
Transect2	pm	8	9			8	9		9	26
TBC3	am	9	27	7	11	8	19		4	13
TBC3	pm	8	34			8	34		8	20
Transect3	am	10	31	10	29	10	30		10	20
Transect3	pm	15	31			15	31		9	42
TBC4	am	13	21	11	39	12	30		12	28
TBC4	pm	7	16			7	16		10	31
Transect4	am	13	37	7	15	10	26		8	30
Transect4	pm	3	4			3	4		11	31
TBC5	am	10	13	7	29	8.5	21		5	9
TBC5	pm	5	13			5	13		4	13
Transect5	am	8	17	6	9	7	13		8	11
Transect5	pm	12	26			12	26		5	13
TBC6	am	11	31	7	18	9	24.5		12	16
TBC6	pm	6	9			6	9		12	41

Table 3.2.1.2.5 Diesel oil residues detected in pre- and post-explosion soil samples collected at Kotoloname. K = Pre-control; KC = post-control in craters; KL = 10m left of craters; KR = 10m right of craters.

Pre explosion samples:

Field code	Sampling Date	Lab Code	Diesel oil Residue, mg/kg
K 10/1	10.3.05	21/05	0.07
K 10/2	10.3.05	22/05	0.04
K 10/3	10.3.05	23/05	0.08
K 10/4	10.3.05	24/05	0.07
K 10/5	10.3.05	25/05	0.06
K 10/6	10.3.05	26/05	0.07
K 10/7	10.3.05	27/05	0.06
K 10/8	10.3.05	28/05	0.07
K 10/9	10.3.05	29/05	0.06
K 10/10	10.3.05	30/05	0.09
K 10/11	10.3.05	31/05	0.18

Post explosion samples:

KC 10/1	18.3.05	32/05	1.20
KC 10/2	18.3.05	33/05	4.78
KC 10/3	18.3.05	34/05	3.32
KC 10/4	18.3.05	35/05	9.31
KC 10/5	18.3.05	36/05	6.70
KC10/6	18.3.05	37/05	5.75
KC 10/7	18.3.05	38/05	2.54
KC 10/8	18.3.05	39/05	7.52
KC 10/9	18.3.05	40/05	2.16
KC 10/10	18.3.05	41/05	1.08
KL 10/1	18.3.05	42/05	0.16
KL 10/2	18.3.05	43/05	3.12
KL 10/3	18.3.05	44/05	0.28
KL 10/4	18.3.05	45/05	0.63
KL 10/5	18.3.05	46/05	0.34
KL 10/6	18.3.05	47/05	0.20
KL 10/7	18.3.05	48/05	0.25
KL 10/8	18.3.05	49/05	0.13
KL 10/9	18.3.05	50/05	0.39
KL 10/10	18.3.05	51/05	0.06
KR 10/1	18.3.05	52/05	0.25
KR 10/2	18.3.05	53/05	0.18
KR 10/3	18.3.05	54/05	0.20
KR 10/4	18.3.05	55/05	0.29
KR 10/5	18.3.05	56/05	0.20
KR 10/6	18.3.05	57/05	0.37
KR 10/7	18.3.05	58/05	0.16
KR 10/8	18.3.05	59/05	0.31
KR 10/9	18.3.05	60/05	0.25
KR 10/10	18.3.05	61/05	0.21

Figure 3.2.1.2.1. A Sonogram of the tape recording of the explosion on 17 March 2005.

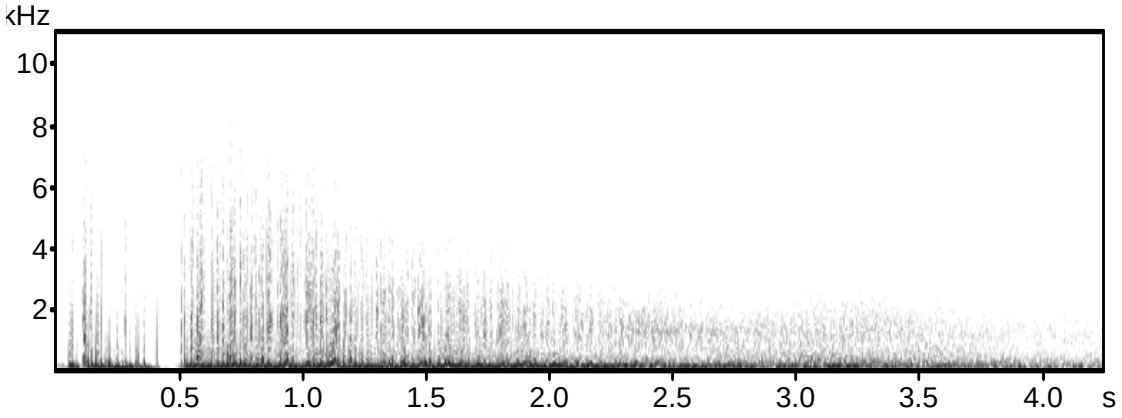


Figure 3.2.1.2.2. GLC trace from a pre-explosion sample.

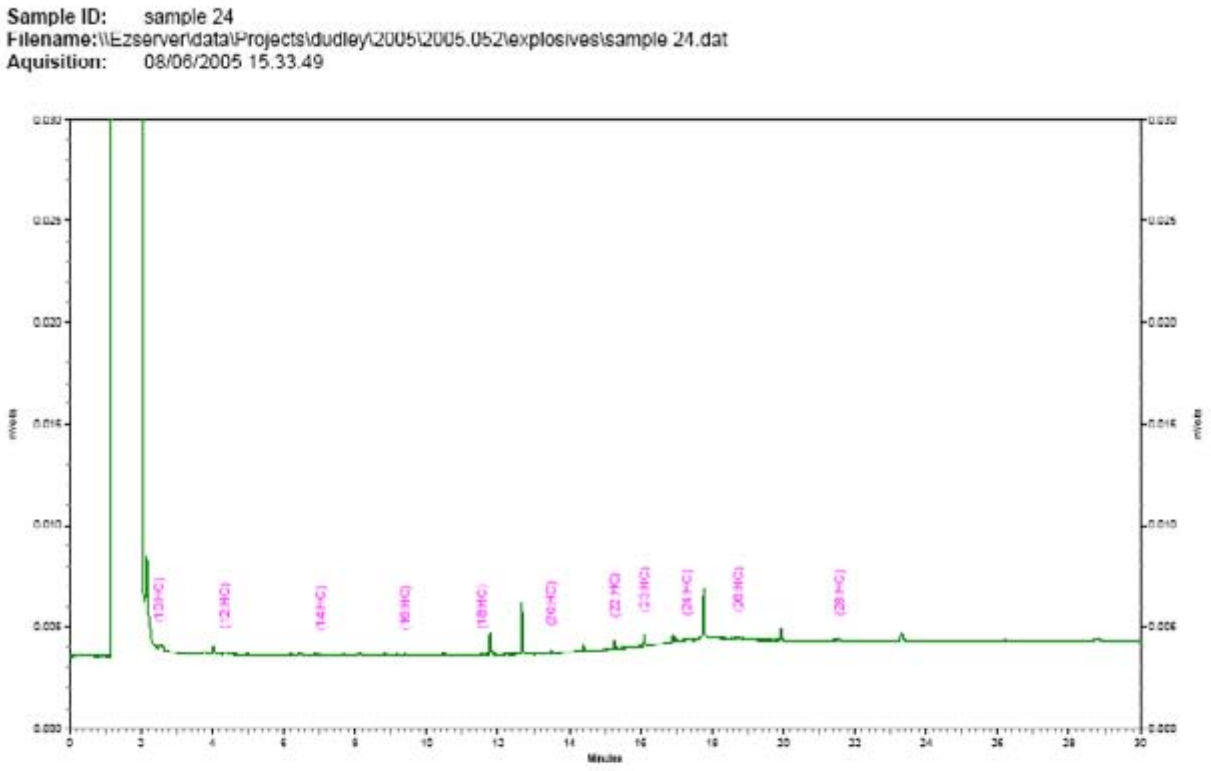
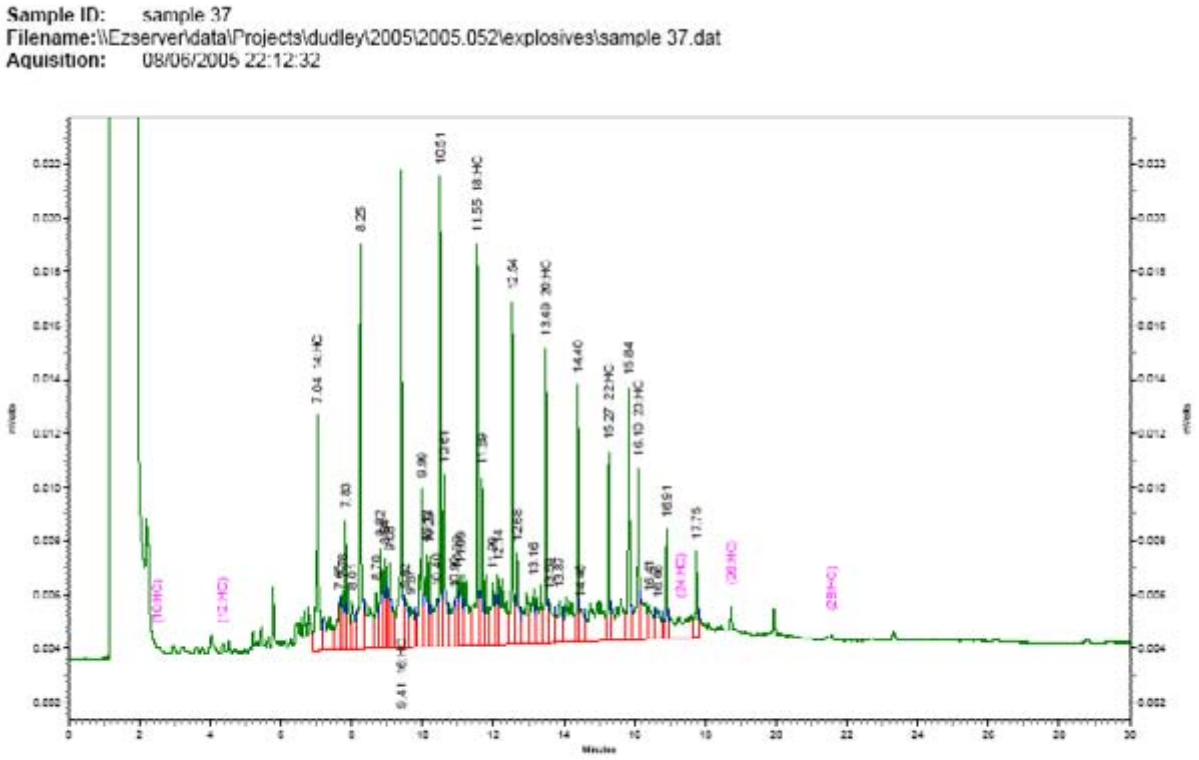


Figure 3.2.1.2.3. GLC trace from a post-explosion sample showing different hydrocarbon peaks, fractions from diesel and petrol pollution.



3.2.2. *Potential for exploitation of quelea bird chicks as a source of protein for people and as an environmentally safe means of control investigated.*

Farmer interviews on quelea harvesting

On 24 February 2005 the Bobonong area of Botswana was visited to seek information on the exploitation of quelea birds for food by those living in the region. At Bobonong, Mr Reginald Gumbalume (Bobonong District Plant Protection Officer) informed us that on 12 December 2002, the Ministry of Agriculture had organised a workshop on Quelea as social food. Eighty-five farmers had attended. The workshop conclusion was that the farmers do not wish quelea breeding colonies in their area to be sprayed. Requests had been made for the Ministry to supply vehicles to transport the farmers to the sites of the colonies so that they could harvest them, cook them, dry them and sell them.

On 25 February, surveys with Babirwa people were conducted at three villages (Semolale [21°52'S, 28°50'E], Gobojango [21º49'S, 28º44'E] and Mabolwe [21º 49'S, 28º 49'E]) in the Bobonong (21º 58'S, 28°25'E) area. Other villages where quelea were also harvested included Molalatau (22°04'S, 28°36'E), Mathathane (22°07'S, 28°16'E) and Motlhabeng (22°02'S, 28°20'E). During the surveys, the same set of questions (Table 3.2.2.1.) were asked and at each village the replies were similar and quelea were reported as being harvested at each. When colonies were present, both chicks and adults were taken as food and eaten by adults and children of both genders. The harvests were mostly for home consumption but some were sold (1 pula for 10) locally. The harvesting method for chicks involved using a long stick with a hooked end to bring branches with nests down to a reachable level and to collect them from the nests, or from the ground if fallen. Adults were harvested at night, usually on moonless nights, by men, women and children. Fires were sometimes lit beneath trees, forcing the birds to move to the edges where they were struck with sticks and collected into bags. After plucking, the birds' intestines were removed and the bodies boiled in salted water. They were then dried on top of sacks placed in the sun. Birds prepared in this way could be stored for at least one month. Immediate consumption after frying was also reported. The harvesting was a communal activity and repeated night after night until the surviving birds fled, thus it acted as a crop protection measure, which was reported at Gobojango and Mobelwe as the primary intention of the harvesting. The consensus was against the spraying of colonies for both environmental reasons and so that the birds could be harvested for food, a benefit that outweighed any crop damage. Difficulties in reaching the colonies and transporting the harvests led to the requests for the provision of lorries to transport people from the villages to any nearby colonies. Other requests included the need for a market where the produce could be taken for sale and assistance in any means of packaging them.

Quelea are also eaten in other parts of Botswana. At Shorobe, 38km north of Maun, local people do not visit colonies or harvest nests at night but they do catch birds while they feed on grass around the fields by throwing a knobkerry into dense congregations. It was claimed that they can hit up to 20 birds per throw, but it is mainly small boys who do the catching. Villagers are prepared to pay 50 thebe to 1 pula per bird from the small boys. At Shakawe it was said that metal coat-hangers are used to bring the birds down but at Lake Ngami, drop traps placed over bowls of water were used to trap birds coming to drink.

Table 3.2.2.1. Questions posed to villagers at Gobojango, Semolale, and Mabolwe (F = female; M = Male).

Question		**Village**		
		Gobojango	***Mabolwe***	***Semolale***
	Respondents	3F, 2M	7F, 10M	7F, 10M
1. Do people in your village eat quelea birds?		Yes	Yes	Yes, except one girl said she did not because she disliked the taste. The village has a population of 1000 and everyone eats quelea.
2. If yes to Q1, do they eat chicks, adults or both?		Both	Both but especially small chicks as easier to catch, lack hard bones and have fewer feathers.	Both
3. Do adults eat them or just children or both?		Both	Both	Both
4. If adults eat them are they male or female or of both genders?		Both	Both	Both
5. Are harvested birds for your own consumption or do you sell them?		Some are for us, others we sell	Most are for home consumption. One person sells them.	All are for home consumption. We do not sell any.
6. If you sell them, what do you charge?		2 Pula for a full Tupperware container. They are too insignificant for bulk selling	Adults are sold at 10 Tebi each or 1 Pula for 10.	n/a
7. How do you catch the birds?		Both men and women are involved in the captures. (A) For chicks a hooked branch is used to pull nests down and chicks falling out are collected from the ground. Those with some feathers are preferred. (B) The colony is visited at night (best on moonless nights) and the	Same method used as described for Gobojango but fires are not used. Lights are taken to search for grounded birds.	Same method used as described for Gobojango and Mabolwe. One man reported capturing them in fields with drop traps.

	birds are beaten with sticks to get them. Sometimes fires are lit below, forcing birds to the edges of the bushes where they are attacked with sticks.		
8. How do you avoid injury from the thorns in the bushes that they usually nest in?	We do not avoid them, we just suffer the scratches	No protection used.	Shoes are worn and lights are carried.
9. Can anyone who wants to collect the birds?	Yes. Whoever sees them first gathers people together and liaises with others for the forays.	Yes. Everybody goes. Women cut trees to make paths. There are no restrictions on who goes anywhere and the harvesting is not organised.	Yes. A group goes. Children are seldom involved as the work is done late at night.
10. How many do you take?	It depends on the individual	As many as possible. We go every day until it is no longer worth it.	It depends on the individual. There is no limit.
11. How do you prepare the birds for eating?	They are plucked (takes 2 minutes per bird) and intestines are removed before boiling in salted water. After sun-drying they are eaten dry or re-heated. The most palatable are chicks with feathers about to sprout as their bones have not formed properly.	Same method as described at Gobojango. Dried birds are kept for up to one month. One lady reported keeping them for 2 months when they were still edible.	Same method as described at Gobojango and Semolale with the variation that legs and heads are removed, only the torso being boiled and eaten. Also some are fried for immediate consumption.
12. Do you always eat them if they are available or only if there is a food shortage?	All colonies are harvested	We always catch them if they are available even if we already have relish in the house.	
13. How often do you eat them?	Whenever possible. The last catch was at the beginning of 2002.	Whenever possible. The last catch was at the in 2003, but we feared pesticide contamination as we knew that the Ministry of	We always catch them if they are available.

		Agriculture was aware of the colony.	
14. Do you have Any comments to make about quelea harvesting?	We need transport to reach the colonies. We are seeking cooperation from other villages to seek transport communally. We need transport to reach markets.	Our method works but not to the same extent as chemicals would. In outbreak years, even chemical methods are insufficient. We intend to reduce them to acceptable levels not to eradicate them.	We need training in corn cricket and quelea control.
15. What animals or birds have you seen eating quelea?	Foxes, kites, eagles, snakes	Wild cats, civets, foxes, squirrels, porcupines, kites, vultures, storks, snakes. Cows may eat the bones of contaminated dead birds.	Foxes, vultures, kites, eagles, snakes, leguans
16. Do your activities reduce the populations or do the birds still attack your crops?	Crop protection is the main aim. The surviving birds flee so crops are protected. As many people as possible attack the birds repeatedly until they have gone.	Crop protection is the main aim. We try to disturb the colonies to force the birds away but this is impossible if the colony is very large.	There is no reason for the harvesting, it is now customary. We harvest for food not for crop protection, for which it has little effect.
17. Do you prefer to catch and eat the quelea or have them controlled?	It is best if the birds are not sprayed. As we are concerned about the effects on wildlife. Hyaenas, foxes and birds of prey die after eating poisoned birds.	We prefer to harvest the quelea. After spraying we have seen dead foxes, dogs, squirrels, aardvark, vultures, crows and leguans. Sprays could affect children and livestock and poison underground water. Spraying is expensive and the money could be used better.	We prefer the opportunity to harvest them. We have seen foxes, dogs, kites and birds of prey dead after spraying.
18. Were more birds eaten in earlier times?	No. The situation is the same, it depends on the rains. We do not like pesticides. In the past we accepted the	There used to be plenty but chemical control has reduced them. We used to plant more sorghum that they like. Now we plant more beans and maize that they	No. Children are now less interested in the activity.

	presence of quelea and harvested them.	do not like.	
19. Any comments on possibilities for improved processing and marketing of the birds?	Many would be interested. We need training on how to preserve then and we would like to test drying them as biltong. Packaging methods are needed e.g. vacuumed plastic wraps. We need to look for a market for the birds. Young people are still interested. It is the consensus of the whole district that they like to eat the birds and are opposed to the spraying.	We need transport. Many colonies are too far way to reach with donkey carts. If we had transport we would do more harvesting and then market the birds. We need longer poles for the hooks, protective clothing, camping equipment and means to refrigerate the birds. The colonies here are too small to make commercialisation worthwhile and the market is unpredictable.	Transport is needed and a market if they could be sold. We would go up to 20-30km to harvest the birds. We need five 5 ton trucks to ferry us to the sites.

3.3. Report on activities to achieve output 3. Protocols on environmental assessment of quelea control devised and standardised for dissemination as regional policy objective.

3.3.1. *Standardised protocols for monitoring effects of quelea control on non-target organisms devised.*

The field work permitted the assessment of the feasibility of various techniques for the assessment of the environmental effects of control methods used against quelea. In the light of this and other experience, the following set of protocols could be adopted as guidelines by monitoring teams elsewhere and provide the basis for the collection of comparative data throughout Africa. The protocols include procedures for studies that we were unable to complete during the work described above (section 3.2.1.), such as sampling vegetation and invertebrates, but these could be undertaken by larger teams or by teams with personnel with additional or different expertise. Further details of procedures for the investigations described above (except the cholinesterase monitoring) and other environmental monitoring methods that could be used at quelea colonies have been summarised by Grant and Tingle (2002).

RECOMMENDED MONITORING PROTOCOLS

1. Control decision

A decision to undertake control operations against a particular colony or roost should not be taken lightly. If the birds are feeding on grass seeds and/or insects and are not threatening any crop then there is little justification for control. Spraying should not take place near bee-hives or water or within environmentally sensitive areas.

2. Safety

Before entering a recently controlled zone, investigators should wear protective clothing (overalls, masks, goggles, rubber boots, nitrile rubber gloves).

3. EIA decision

A decision on which of the methods listed below will be used must be made at the outset. This will depend upon available man-power, their expertise, time constraints and resource considerations.

4. Soil sampling for levels of pesticides (to be repeated before and after control applications and at intervals after control, if possible)

4.1. Sampling. Select about five widely spaced sampling sites per contaminated area and collect at least 4 random soil samples at each of the five sites. Samples to consist of 100-200g from the top 7cm of soil and to be placed in clean cloth bags for air drying. Record location of each sample with GPS.

4.2. Preserving. Air-dry the soil in the bags in shade to reduce the moisture content until the samples are dry and friable. Then remove stones and vegetation and pass each sample through a 2-4mm sieve as an aid to homogenisation. Take two sub-samples of 100g from the mixture, store in labelled aluminium containers or foil for analysis. If using the latter, double wrap the foil and label the external layer with sample details. A separate check list detailing all the samples should be sent with the samples to the analytical laboratory. Maintain samples deep-frozen until analysis.

5. Vegetation sampling

5.1. Sampling. Select three widely spaced sampling sites per contaminated area and mark 3 randomly chosen sample points at each site with numbered stakes. Take position of sites with GPS. Collect vegetation before spraying, immediately after spraying, on days 1, 3, 7 and if possible on day 10 post-spray. Samples to consist of 100g randomly cut from the top 10cm of cover at the three sample points in each of the three sites. Place immediately in labelled aluminium foil. Deliberately contaminate one of the three unsprayed samples collected from each site with a known amount of the pesticide being used to determine percentage recovery of the pesticide following storage.

5.2. Preserving. Specimens should be kept cool until analysis.

6. Assessment of changes in insect populations

6.1. Sweep-netting. Mark out 5 x 100 m transects spaced equally at least 100m apart within the centre of control and experimental plots, then take 20 'standard' sweeps at roughly 5m intervals for each transect. This should be performed by the same worker on all occasions to reduce bias and the nets' contents transferred to strong, sealed polythene bags at the end of each transect. Insects are then sorted from debris and preserved in 70% alcohol for subsequent counting and identification. To detect short term effects, pre-spray sampling needs to be carried out on a minimum of three separate days before pesticide application and at least on days 1, 3, 7 after spraying and preferably on days 10 and 14 as well. Monthly sampling over an annual cycle would be required to make an assessment of long-term impact of a one-off control operation.

6.2. Malaise Traps. Place a minimum of 3 malaise traps (to assess within treatment variability) at least 100m apart within the middle of both treated and control blocks. Orientation should be at right angles to the prevailing wind. The collection bottle can be half filled with 5% formalin as a killing and preserving agent, to which is added a drop of detergent and some glycerol to reduce surface tension and evaporation respectively. Catches should be collected and containers recharged every 24 hours, preferably in the early morning, and insects transferred to 70% alcohol for later identification in a laboratory.

7. Assessments of changes in bird populations

7.1. Transects conducted on foot. Use timed bird counts and transect methods before and after spraying as described above, with timed counts interspersed along a series of at least 5 transects of at least 100m in length each. The times and lengths of transects may be varied in relation to the resources available and the size of the colony or roost. If time permits, then comparisons should be made between a control area and the zone to be treated when two 1km transects should be marked at least 500m apart in the middle of both control and experimental blocks. Maintain a slow fifty-minute walk for each transect by covering 100m sections in 5 minutes at a uniform pace and record all birds seen or heard within 50m of the path. Counts to be done by the same observer on a daily basis in the early morning, alternating between replicate transects on a daily basis.

7.2. Transects conducted by vehicle. If very large colonies or roost are involved, this method may be used to record all birds seen or heard within a 5 minute period and within 100m of the vehicle at sample points separated by 500m along replicate tracks of at least 5km in length.

8. Carcass searches

These are required to measure direct mortality of vertebrates from pesticide application within treated blocks and require as many observers as possible. It is suggested that at least 10 people walk abreast 10m apart for a minimum of 1 km

through the middle of both control and sprayed blocks, 24 hours, 48 hours and if possible 72 hours after treatment. Any carcasses found should be placed in aluminium foil and frozen for subsequent residue analysis following identification. A record should be kept of search effort in man-hours to help make comparisons of relative mortalities between colonies.

9. Clearing-up

Dead quelea should be removed from sprayed sites to prevent secondary poisoning and buried at a safe site. Plastic containers and other material used for control with explosives should be collected, removed from the site and disposed of safely.

10. Pre- and post-control scaring of non-target animals.

Non-target animals, particularly raptors, should be scared from colonies before control and kept away for two days following treatment while residue levels decline. In Zimbabwe, beaters have been used to disturb reed beds containing many water birds and other species during the late afternoon before aerial spraying began. After spraying, no non-target birds were found in a search that yielded 26,400 dead quelea (Mundy & Packenham 1988).

11. Reporting

Results of the EIAs conducted must be described in reports that can be made available for other investigators. This could be achieved by posting them on websites such as those maintained by the Information Core for Southern African Migrant Pests (ICOSAMP) or by the Southern African Development Community (SADC).

3.3.2. *Protocols evaluated in field (Mar. 2004) and promoted within SADC through ICOSAMP network.*

The field work in March 2004 and March 2005 provided opportunities to test the procedures on bird censuses and soil collections described in the protocols. No difficulties were encountered but many of the other methods remain to be evaluated for sampling in quelea habitats. Dissemination of the protocols within SADC through the ICOSAMP website was delayed until May 2005 when the ICOSAMP project leader will be met at a workshop in Kenya. At that meeting, it is intended to discuss the protocols with stakeholders from eastern Africa so that a revised version is likely to be available for dissemination by June 2005.

3.4. Report on activities to achieve output 4. Parallel running of southern Africa quelea model in conjunction with target institution.

3.4.1. *Existing model for quelea forecasts in southern Africa run in parallel with target institution's version for quality control and website improved.*

The existing quelea model was run throughout the 2003/2004 and 2004/2005 seasons and all of the weekly model output maps are available as archives on the NRI quelea website (http://www-web.gre.ac.uk/directory/NRI/quel/Index.htm). The software for running the model was handed over to staff of the Regional Remote Sensing Unit (RRSU) of the Food, Agriculture and Natural Resources (FANR) section of the Southern African Development Community (SADC). When the FANR team were still based in Harare, they ran a separate version of the quelea model and displayed their output on their website (http://www.sadc-fanr.org.zw/rrsu/quel/latest.htm) from the start of the season until January 2005 when they were transferred to Gaborone. This led to an interruption of the parallel running of the models (but the forecasts were continuously available on the NRI site) but it is expected that they will be able to continue and run the model for the 2005/2006

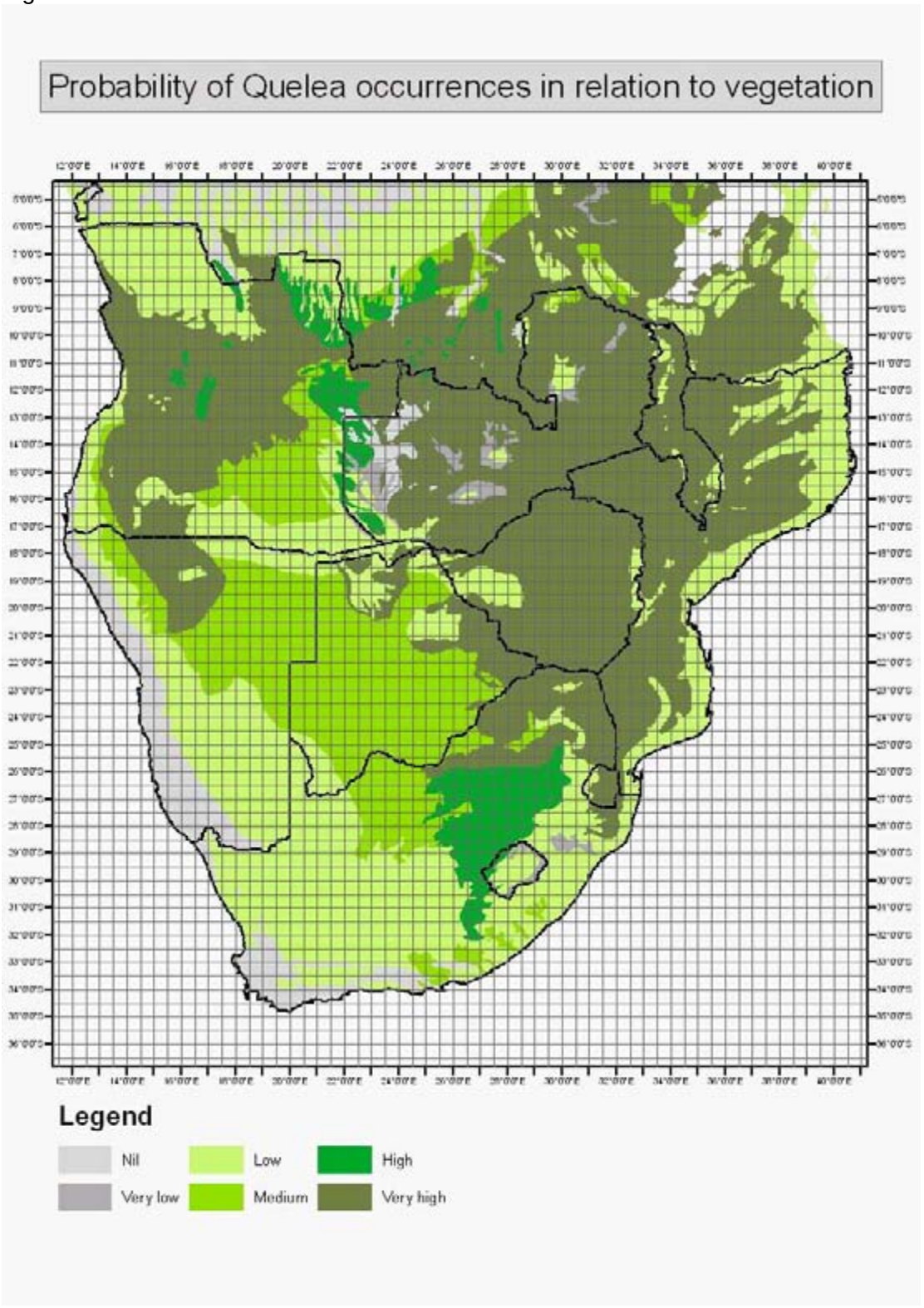
season. When the models were running in parallel the two sets of outputs were almost identical demonstrating that the software and its running had been successfully transferred to the FANR team.

The NRI website was improved by the addition of pdf files of relevant publications and maps (see below).

3.4.2. *Existing model for quelea forecasts in southern Africa improved to include probability weightings based on frequencies of occurrence and soil characteristics and vegetation suitabilities.*

The numbers of quelea colonies reported in different 0.5° X 0.5° squares were analysed in relation to the vegetation, soil and proximity to water in each square. These data were then used in ARCGIS software to produce maps showing the distribution of quelea breeding colonies in relation to these factors. The maps (Figures 3.4.2.1 illustrates that for vegetation) were added to the website, where they were explained and included within a section entitled “Refining the forecasts”. This permits users to interpret the model output more effectively by being able to take account of environmental conditions in different grid squares at a resolution of 0.5° X 0.5°.

Figure 3.4.2.1.


Probability of Quelea occurrences in relation to vegetation
Legend
Nil
Low
High
Very low
Medium
Very high

3.4.3. *Website with model outputs expanded to include information on quelea biology and control.*

A section entitled publications was added to the website that provided access to pdf files of recent publications on the biology and control of quelea.

3.5. Miscellaneous achievements

3.5.1. Blood samples and associated blood smears collected during this project and earlier CPP-funded projects on quelea birds were sent to the Smithsonian Institute for investigations on the birds' blood parasites. This was achieved by both microscopic identification of protozoa in stained blood smears and by molecular analyses. Much higher levels of infection were found than in previous studies of the haematozoa of *Q. quelea*. Using molecular methods, the prevalence of infection and the frequency of mtDNA and DHFR-TS lineages of haematozoans (*Plasmodium* and *Haemoproteus*) in birds sampled from both sides of the migratory divide in the interior of Southern Africa (Zimbabwe) were assessed. In a survey of nearly 150 birds covering the span of the divide very high prevalence values per site (34-70%) were found. Thirteen distinct *Plasmodium* and seven distinct *Haemoproteus* mtDNA lineages among the quelea samples were identified. There were no differences in the distribution of particular lineages of *Haemoproteus* or *Plasmodium* between the divide, but there was a significant difference in apparent parasite prevalence, with prevalence being higher southeast of the migratory divide than within the divide (central) or northwest of the divide. The results will be interpreted in a future publication with regard to any ecological factors that may drive the prevalence differences and discussed in relation to why the migratory divide does not appear to limit dispersal of parasite lineages.

3.5.2. Moult study. Samples were supplied from a breeding colony that was active very late in the 2003/2004 season near Francistown described by Bousfield (2005). The birds had been collected on 19 June 2004 and frozen until examined in March 2005. After examination of their moult it was clear that they had delayed the onset of their moult or interrupted moulting, with 18 males having an average moult score of 5 and 24 females averaging 5.75. Five of the males and 10 of the females had not started to moult at all.

Ackowledgements
The DFID Crop Protection Programme is thanked for its support. The work would not have been possible without the active participation of staff of the Crop Protection Division of the Ministry of Agriculture of Botswana, particularly Mr M. Modise, Ms R. Kgosi, T. Moruti, C. Mbereke, P. Malikongwa and M. Mmopi. Dr A. N. McWilliam and C. Mbereke contributed very substantially to the EIA and quelea harvesting work. We thank Sgt. Lesedi Menyatso for coordinating the blasting operation. P. Eberly supplied the cholinesterase analysis kits and much advice on their use. John Cox and Dudley Farman analysed the soil samples. The website was run by J. F. Venn and N. R. Saddi made substantial contributions to the modelling and the website. B. Siwela ran the model on the SADC-FANR website. K. iddi produced the sonogram. N. Bousfield supplied specimens of quelea. Wendy and Remi Borello provided hospitality and assistance in numerous very generous and helpful ways in Gaborone and Barry and Elaine Pryce provided advice and much help in Shakawe.

References

Adam, G. & Duncan, H. (2002) Influence of diesel fuel on seed germination. *Environmental Pollution* 120: 363-370.

Allan, R. G. (1997). *The Grain-eating Birds of Sub-Saharan Africa. Identification, Biology and Management*. Natural Resources Institute, Chatham, UK.

Bibby, C. J., Burgess, N. D. & Hill, D. A. (1992). *Bird Census Techniques*. Academic Press, London.

Bousefield, N. (2005) A red-billed quelea Quelea quelea breeding colony, May/June 2004. *Babbler* 45:30-33.

Busby, D. G., White, L. M. & Pearce, P. A. (1990) Effects of aerial spraying of fenitrothion on breeding white-throated sparrows. *Journal of Applied Ecology* 27: 743-755.

Coye, M. J., Lowe, J.A. & Maddy, K.T. (1986) Biological monitoring of agricultural workers exposed to pesticides. I. Cholinesterase activity determinations. *Journal of Occupational Medicine* 28: 619-27.

Dallimer, M., Jones, P. J., Pemberton, J. M. & Cheke, R. A. (2003) Lack of genetic and plumage differentiation in the red-billed quelea *Quelea quelea* across a migratory divide in southern Africa. *Molecular Ecology* 12: 345-353.

Elliott, C. C. H. (1989) The quelea as a major problem in a food-deficient continent. pp. 90-99 in P. J. Mundy & M. J. F. Jarvis (eds) *Africa's Feathered Locust*. Baobab Books, Harare, Zimbabwe.

Ellman, G.L., Courtney, K.D., Andres, V., Featherstone, R.M. (1961) A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochem. Pharmacol.* 7: 88-95.

Geertsema, L. (1998) Redbilled Quelea: Annual Report. Unpublished report, National Department of Agriculture, South Africa.

Grant, I. F. & Tingle, C. C. D. (eds) (2002) *Ecological Monitoring Methods for the Assessment of Pesticide Impact in the Tropic*s. Natural Resources Institute, Chatham, U.K.

Grue, C.E., Hart, A.D.M. & Mineau, P. (1991). Biological consequences of depressed brain cholinesterase activity in wildlife. Pp. 151-209 in Mineau, P. (ed.) Cholinesterase-inhibiting Insecticides. Elsevier Science Publishers B.V., Amsterdam.

Jones, P.J. (1989a). General aspects of quelea migration. pp102-112. In: Bruggers, R.L. & Elliott, C.C.H. (eds). *Quelea quelea* - Africa's bird pest. Oxford: Oxford University Press.

Jones, P.J. (1989b). Distribution, populations, and migration patterns of quelea in southern Africa. pp132-143. In: Bruggers, R.L. & Elliott, C.C.H. (eds). *Quelea quelea* -Africa's bird pest. Oxford: Oxford University Press

Jones, P. J., Cheke, R. A., Mundy, P. J., Dallimer, M. & Venn, J. F. (2000) Quelea populations and forecasting based in southern Africa. Pp. 139-150 in Cheke, R.A., Rosenberg, L.J. & Kieser, M. (eds.) *Proceedings of a Workshop on Research Priorities for Migrant Pests of Agriculture in Southern Africa*, Plant Protection Research Institute, Pretoria, South Africa, 24-26 March 1999. Natural Resources Institute, Chatham, UK.

Kingdom, J. (1997) *The Kingdom Field Guide to African Mammals*. Academic Press, London.

Lawson, A.A. & Barr, R.D. (1987) Acetylcholinesterase in red blood cells. *American Journal of Hematology* 26: 101-12.

Magnotti, R. A., Dowling, K., Eberly, J.P. & McConnell, R.S. (1988) Field measurement of plasma and erythrocyte cholinesterases. *Clin Chim Acta* 176: 315-332.

McWilliam, A. N. & Cheke, R. A. (2004) A review of the impacts of control operations against the Red-billed Quelea (*Quelea quelea*) on non-target organisms. *Environmental Conservation* 31: 130-137.

Mundy, P.J. & Pakenham, C.J. (1988) Control of Queleas roosting at McIlwaine. *Honeyguide* 34: 132-133.

Richards, P., Johnson, M., Ray, D. & Walker, C. H. (1999) Novel protein targets for organophosphorus compounds. In E. Reiner, V. Simeon-Rudolf, B. Doctor & C. E. Furlong (eds.). Esterases reacting with organophosphorus compounds. *Chemico-Biological Interactions* 119-120 (special issue): 503-512.

Sinclair, I. & Ryan, P. (2003) *Birds of Africa South of the Sahara*. Struik Publishers, Cape Town.

Thompson, H.M. (1999) Esterases as markers of exposure to organophosphates and carbamates. Ecotoxicology 8: 369-384.

van der Walt, E. (2000) Research at PPRI on environmental effects of quelea control operations. pp. 91-95. In: *Workshop on Research Priorities for Migrant Pests of Agriculture in Southern Africa, Plant Protection Research Institute, Pretoria, South Africa, 24-26 March 1999*. Cheke, R.A., Rosenberg, L.J. & Kieser, M.E. (eds). Natural Resources Institute, Chatham, UK.

van Der Walt, E., Meinhardt, H.R., Venter, J.A. & Bouwman, H. (1998) Primary and secondary effects of Red-billed Quelea *Quelea quelea* control in South Africa. Abstract *In*: Adams, N.J. & Slotow, R.H. (eds) *Proceedings of the 22nd. International Ornithological Congress, Durban. Ostrich* **69**: 456.

Venn, J., Cheke, R.A. & Jones, P. J. (2003) Forecasting breeding opportunities for the red-billed quelea in southern Africa. Pp. 612-617 in Proceedings of the 2003 EUMETSAT Meteorological Satellite Conference, Weimar, Germany, 29 September - 3 October 2003. EUMETSAT, Darmstadt, Germany (ISBN 92-9110-064-1; ISSN 1011-3932).

Walker, C.H. (2003) Neurotoxic pesticides and behavioural effects upon birds. Ecotoxicology **12**: 369-384.

Wang, X. & Bartha, R. (1990) Effects of bioremediation on residues, activity and toxicity in soil contaminated by fuel spills. *Soil Biol. Biochem*. 22: 501-505.

Ward, P. (1971) The migration patterns of *Quelea quelea* in Africa. *Ibis* **113**: 275-297.

Whitaker, M. (1986) Cholinesterase. In: Monographs in Human Genetics Vol.11.Basel, Karger.

4. Outputs

All outputs were achieved.

1. Capacity of target institution staff to conduct environmental monitoring of quelea control enhanced.

A week-long training course on *Environmental impact assessment of quelea bird control* was run at Sebele, near Gaborone, Botswana from 16 to 21 February 2004. The course consisted of formal lectures and practical work in the field, including a visit to a recently controlled quelea breeding colony. Sixteen members of the Plant Protection Division of the Ministry of Agriculture attended. They included the Head of the Pesticide Management Section, the Head of the Pest Management Section, six Regional Plant Protection Officers, six District Plant Protection officers and two Agricultural Scientific Officers. One of the latter, assigned to EIA duties, then accompanied project members in the field in both 2004 and 2005. During the field work this officer was trained in pre-and post-control EIA procedures and put into practice at a quelea breeding colony sprayed with fenthion in March 2004 and at a quelea roost controlled with explosives in March 2005. He was given appropriate equipment and training to continue EIA work in Botswana.

2. Field evaluation of environmental impact of quelea control in Botswana.

The environmental impact of the control of a quelea breeding colony sprayed with fenthion in March 2004 was assessed. It was confirmed by analyses of their acetylcholinesterase (AChE) and butyrylcholinesterase (BChE) levels that non-target birds had been affected but the numbers impacted were low. Levels of fenthion were detected in soil samples and were uneven, thus spraying procedures could be improved by better calibration and care to maintain uniform distribution rates. Transect and point count assessments of non-target birds did not reveal any evidence of significant decreases after the spraying operation. In March 2005 a similar study was conducted before and after the control with explosives of a quelea bird roost. Only seven non-target vertebrates (three birds and four mammals) were detected in the 3 ha area that was affected. However, there was substantial pollution from the remains of unburnt plastic containers and diesel, petroleum and plastcics contamination of soil. Further literature searches on the implications of such contamination will be completed shortly and submitted with later reports.

Interviews were conducted with farmers in the Bobonong region of Botswana. It was confirmed that they prefer that quelea breeding colonies are left uncontrolled so that they can harvest chicks and adult birds from them to use as food and, in some cases, for sale. Similar practices were recorded in other parts of the country where less systematic and more opportunistic harvesting occurs.

3. Protocols on environmental assessment of quelea control devised and standardised for dissemination as regional policy objective.

Protocols for the environmental assessment of quelea control were proposed and will be disseminated to SADC countries for consideration for adoption as a regional policy. The protocols include sections on (a) Control decision; (b) Safety; (c) EIA decision; (d) Soil sampling for levels of pesticides (to be repeated before and after control applications); (e) Vegetation sampling; (f) Assessment of changes in insect populations; (g) Assessments of changes in bird populations; (h) Carcass searches; (i) Clearing-up; and (j) Reporting.

4. Parallel running of southern Africa quelea model in conjunction with target institution.

The model for predicting where and when areas within southern Africa become suitable for breeding by Red-billed Quelea, which was developed under a previous CPP project, was run throughout the 2003-2004 and 2004-2005 seasons in parallel with the independent running of the model by the Remote Sensing Unit of the SADC FANR. A link to both models was put on the ICOSAMP website.

5. Dissemination outputs

Publications

CHEKE, R. A. (2003) Environmental impacts of quelea control and a model for forecasting quelea movements and breeding in southern Africa. pp. 58-65 in M. E. Kieser (ed.) Proceedings of the ICOSAMP Workshop, 21-23 May 2002, Pretoria, South Africa.

CHEKE R. A., VENN, J. F., TODD, M. C., KNIVETON, D., WASHINGTON, R. & JONES, P. J. (2003) Analyses of a long-term data-set on the Red-billed Quelea *Quelea quelea lathamii* in southern Africa. Poster presented at the Edward Grey Institute / British Ornithologists' Union annual conference on "Long Term studies of Birds", University of Oxford, 11-16 April 2003.

DALLIMER, M., JONES, P. J., PEMBERTON, J. M. & CHEKE R. A. (2003) Lack of genetic and plumage differentiation in the red-billed quelea *Quelea quelea* across a migratory divide in southern Africa. *Molecular Ecology* 12: 345-353.

CHEKE R. A., JONES, P. J., DALLIMER, M. & GREEN, S. V. (2003) Armoured Bush Cricket attacks on nestling Red-billed Quelea (*Quelea quelea*). *Ostrich* 74: 135.

FLEISCHER, R. C., REED, J. L.,BEADELL, J., DURRANT, K. JONES, P.J., CHEKE, R.A. & MCWILLIAM, A. N. (2005) Prevalence and phylogeography of avian blood parasite lineages in *Quelea quelea.* Abstract of poster presented at 123rd. meeting of the American Ornithologists' Union, University of California, Santa Barbara, U.S.A.

MCWILLIAM, A. N. & CHEKE, R. A. (2004) A review of the impacts of control operations against the Red-billed Quelea (*Quelea quelea*) on non-target organisms. *Environmental Conservation* 31: 130-137.

VENN, J., CHEKE, R.A. & JONES, P. J. (2003) Forecasting breeding opportunities for the red-billed quelea in southern Africa. Abstract. The 2003 EUMETSAT Meteorological Satellite Conference, Weimar, Germany, 29 September - 3 October 2003.

VENN, J., CHEKE, R.A. & JONES, P. J. (2003) Forecasting breeding opportunities for the red-billed quelea in southern Africa. Pp. 612-617 in Proceedings of the 2003 EUMETSAT Meteorological Satellite Conference, Weimar, Germany, 29 September - 3 October 2003. EUMETSAT, Darmstadt, Germany (ISBN 92-9110-064-1; ISSN 1011-3932).

VENN, J., CHEKE, R.A. & JONES, P. J. (2004) Forecasting breeding opportunities for the red-billed quelea in southern Africa. Abstract. p. 302 in Proceedings of the 15th International Plant Protection Congress, Beijing, 11-16 May 2004. Foreign Languages Press.

(Four other papers to be submitted to peer-reviewed journals are in an advanced state of preparation).

Internal Reports:

Cheke, R. A. (2004) Visit to Botswana 12 February 2004 to 9 March 2004 to conduct a training course and field work on the environmental impact of quelea bird control. Back-to-the-office report, NRI, unpublished.

Cheke, R.A., McWilliam, A.N., Mbereke, C., Eberly, J.P., Cox, J. R. & Farman, D. I. (2004) An environmental impact assessment of control with fenthion of red-billed quelea *quelea quelea* at a colony in Botswana and protocols for comparative studies. Unpublished report to CPP.

Cheke, R. A. (2004) Quelea Birds in Southern Africa: protocols for environmental assessment of control and models for breeding forecasts. Progress report 1 April to 30 September 2003. Unpublished report to CPP.

Cheke, R. A. (2004) Quelea Birds in Southern Africa: protocols for environmental assessment of control and models for breeding forecasts. Progress report 1 October to 31 December 2003. Unpublished report to CPP.

Cheke, R. A. (2004) Quelea Birds in Southern Africa: protocols for environmental assessment of control and models for breeding forecasts. Annual report 1 April 2003 to 31 March 2004. Unpublished report to CPP.

Cheke, R. A. (2004) Quelea Birds in Southern Africa: protocols for environmental assessment of control and models for breeding forecasts. Progress report 1 April to 30 September 2004. Unpublished report to CPP.

Cheke, R. A. (2005) Visit to Botswana 17 February 2005 to 23 March 2005 to conduct field work on the environmental impact of quelea bird control. Back-to-the-office report, NRI, unpublished.

Other Dissemination of Results:

Model outputs on website (see http://www-web.gre.ac.uk/directory/NRI/quel/Index.htm)
*Advice on quelea biology to producers of BBC television series "Planet Earth" to be broadcast in 2006 or 2007.

Listing and reference to key datasets generated:

- **(a)** *Dataset of weekly quelea forecasts archived on website (see http://www-web.gre.ac.uk/directory/NRI/quel/Index.htm)
- **(b)** *Data-base on quelea breeding colonies held electronically (in EXCEL) at NRI.

Contribution of Outputs to developmental impact

The increased environmental awareness of plant protection staff in Botswana and the SADC region will lead to (a) fewer decisions to control e.g. where concentrations of non-targets such as storks are present or where the local population will undertake their own control by harvesting quelea colonies; (b) more efficient control and more concern to avoid non-target fatalities and pollution; (c) reduced pollution and (d) enhanced capacity in scientific methods.

The quelea forecasting model was successfully transferred to a target institution for independent running, leading to enhanced capacity and the outputs will lead to better decision-making regarding control with respect to targeting and timing of control actions and with preparedness for control operations and hence more efficient control and reduced crop loss.

To disseminate the results more widely, a follow-up workshop is planned for the 2005/2006 financial year together with expansion of the model to include East Africa. Possibilities for further EIA work in Botswana have been discussed and may be possible if an application by the Ministry of Agriculture to FAO is successful. It is intended to provide further information on the environmental implications of diesel contamination of soil in a future report. Once this has been completed any possible implications for regional policies on quelea control will become clearer.

Biometricians Signature

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:
Name (typed): Mrs Flavia Jolliffe BSc., DIC, CStat
Position: NRI Associate and Consultant Statistician
Date: 8 June 2005