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IMPACT OF FENTHION SPRAYS ON NONTARGET BIRDS DURING QUELEA CONTROL IN KENYA

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In cooperation with

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ABSTRACT

The aerial application of avicides to aggregations of red-billed quelea (Quelea quelea) is the most widespread and presently the most effective method used to control this pest species in Africa. Efforts have been successful to reduce the volume of avicide used in spray operations, but the hazards associated with low-volume spray application techniques to nontarget birds have not been evaluated. In our study, two quelea nesting colonies, 10 and 40 ha in size, were sprayed with 40 L and 100 L of Queletox(R)[4] (60% fenthion), respectively. Fenthion applications caused massive mortality to quelea and insects and brief, but severe exposure of predaceous and insectivorous birds to potentially harmful residues. Environmental and food chain contamination was brief. In both colonies, quelea died during a 4- to 7-day time period, and in the larger colony dead and dying birds were found over an area of at least 35 km^2. Nontarget granivorous bird species appeared unaffected and no evidence of adverse effects on mammals was found. Of 24 radio-equipped raptors tracked for up to 17 days postspray, only one was found moribund and died after spraying. However, several raptors were known to be seriously affected based on cholinesterase inhibition. Primary concerns about using fenthion must be over its lethal and sublethal effects on predaceous and insectivorous birds. Additional studies will be necessary to more fully understand and subsequently minimize the hazards of fenthion to nontarget animals following its use in quelea control.

INTRODUCTION

The red-billed quelea (Quelea quelea) is the most serious avian pest in Africa. It feeds heavily on crops in more than 25 African nations (De Grazio and Besser 1974; Anon. 1981) and, thus, reduces the amount of cereal grains available to farm families, who already face serious food shortages. Regional and national quelea control organizations operating in many African countries traditionally have practiced population reduction to reduce these cereal losses (Ward 1973, 1979; Jaeger and Erickson 1980). Despite efforts to develop nonlethal methods to protect

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[4]Reference to trade names does not imply U.S. Government endorsement.

crops from quelea, spraying quelea concentrations with avicides is still the most effective and widely practiced method. Fenthion (Phosphorothioic acid, O,O-dimethyl O-[3-methyl-4-(methylthio)phenyl]ester), an organophosphate (OP) insecticide marketed as Queletox(R), is the chemical most often used to control quelea. Its use results in an estimated one billion quelea being killed annually in hundreds of nesting colonies and roosts throughout Africa (Ward 1979). Queletox is applied with fixed-wing aircraft, helicopters, and occasionally with ground spraying equipment.

In recent years, there has been a marked reduction in quantities applied as a result of improvements in spray techniques which provide small droplets that remain suspended. However, the chemicals and various application methods have been used without adequate consideration of their possible environmental effects. Desert Locust Control Organization for Eastern Africa (DLCO-EA) and Food and Agriculture Organization of the United Nations (FAO) concern about possible nontarget hazards associated with quelea control has increased in recent years, particularly following a spray operation in Kenya in 1984 where fenthion was applied to roosts on a large wheat scheme using a ground sprayer and low-volume spray techniques. Twenty-four dead or dying eagles, owls, hawks, and secretary birds were recovered following the spray (Thomsett 1984). This mortality seemed to result from raptors being attracted to and eating debilitated birds that dispersed from spray sites (M. Jaeger, pers. obs.). Because quelea control using aerial and ground low-volume application techniques is becoming more widespread, its effects on the environment and nontarget animal species needs to be assessed. The objectives of this study were, therefore, to assess the potential threat of fenthion to nontarget birds when applied by low-volume techniques to quelea concentrations. We determined: (1) the exposure of quelea to fenthion, their postspray dispersal patterns, and their mortality; (2) the attractiveness of treated colonies and affected quelea to raptors and their subsequent exposure to fenthion; (3) the extent of habitat contamination with fenthion; and (4) the effects of fenthion exposure on other birds and, to a lesser extent, on mammals.

Quelea nesting colonies occupy from <1 to >100 ha and contain from a few thousand to several million birds. These colonies can attract large numbers of avian predators, particularly migrant raptors, the numbers of which can progressively increase between the time young quelea hatch and leave the nest. When several colonies occur in one area, young often are in different developmental stages, and raptors may feed on these young birds as they become progressively available. Raptors regularly prey on young quelea, especially during the first 7-10 days after they leave the nest and are still flightless and being fed by adults. In certain habitats, predator density near colonies may be 70-500 times greater than in the general area during this period (Thiollay 1978). Presumably, lethal control operations conducted when flightless young have left the nest and are being fed by their parents would have the greatest adverse impact on raptors.

Predatory birds often are attracted to areas treated with OP's (Zinkl et al. 1979; DeWeese et al. 1983; Thomsett 1984). On numerous occasions,

we have observed increased densities of raptors in or near quelea colonies feeding on dead and dying birds following control operations. Secondary exposure to OP's will kill raptors. A Cooper's hawk, two red-tailed hawks, and an American kestrel died after consuming icterids poisoned with parathion (Stone et al. 1984). Red-tailed hawks have been killed or debilitated by eating famphur-contaminated black-billed magpies (Henny et al. 1985). Birds exposed to OP's may become more susceptible to predation. McEwen and Brown (1966) found that the loss of radio-equipped sharp-tailed grouse to predators increased following their exposure to sublethal doses of malathion and dieldrin.

OP's are the most widely used group of insecticides in North America; this has resulted in concern over their possible effects on wildlife. Grue et al. (1983) found reports of 31 confirmed incidents of wildlife mortality (26 unintentional, 5 intentional) due to OP poisoning in North America, and 747 incidents (387 unintentional and 360 intentional) in other parts of the world. In the unintentional poisonings in the U.S., birds were the animals most frequently reported as being affected.

Fenthion inhibits the enzyme, cholinesterase (ChE), which results in an accumulation of acetylcholine at nerve synapses with consequent disruption of nerve function (O'Brien 1967:55). Most birds appear more sensitive to the acute toxicity of fenthion than mammals (Grue et al. 1983) (Table 1). An LD_{50} is the dose expected to kill 50% of an experimental group; some individuals die at lower doses, while others survive higher doses. The acute oral LD_{50}'s for most bird species range from 2.5 to 25.9 mg/kg (Schafer et al. 1973; Hudson et al. 1984), whereas LD_{50}'s for mammals are in the 100-500 mg/kg range (Schafer 1981). The acute dermal toxicity to bird and mammal species generally is 2-5 times the acute oral dose (Schafer 1984). For quelea, the oral LD_{50} is 1.3 mg/kg (Schafer et al. 1973), and the dermal LD_{50} has been reported to be between 1.8 mg/kg (Schafer et al. 1973) and 2.5 mg/kg (Anon. 1979). Bird mortality from dermal applications generally occurs from 3 to 12 h after exposure, but can take place over a period of days (Schafer 1984). In our studies, we emphasized work with birds because they are more sensitive to fenthion than mammals.

Mortality often is the most obvious effect of OP's on wildlife; sublethal effects resulting from exposure and associated with weight loss may be considerable. Intoxication in wildlife is frequently characterized by anorexia, lethargy, piloerection, antagonistic behavior, miosis and phonation, muscular incoordination, and convulsions or tetany preceding death (O'Brien 1967:56; Tucker and Crabtree 1970; Hudson et al. 1984).

OP's have been used almost exclusively for quelea control during the past 30 years. However, several changes have been made during this period in actual control practices. In eastern Africa, the DLCO-EA, in cooperation with FAO, has tried to minimize the hazards associated with using avicides for quelea control by encouraging the use of chemicals with relatively low mammalian toxicities (i.e., fenthion) and by adopting spray techniques that reduce the volume of avicide applied (i.e., low-volume applications with small droplets; Bruggers and Jaeger 1982). Although the

change from parathion to fenthion was an improvement, the value of the change to lower volume spraying techniques is still questionable.

Keith (1968) indicated that a number of new concerns regarding wildlife must be considered with lower volume spray techniques and that such sprays could result in a more intense exposure of wildlife to pesticides. He stated, "A decrease in the amount of insecticide applied for pest control would be desirable, but amounts applied are not as important as the behavior of the insecticide after it leaves the airplane. Studies show that low-volume application enhances the efficacy of insecticide treatments by increasing deposits and persistence of the insecticides. Prolonged action of an insecticide might be helpful in achieving more complete control of target insects, but could result in increasing the exposure of wildlife from minimal to hazardous levels. More of the insecticide applied is deposited on treated areas with low-volume applications than with conventional spray methods. Initial residues are often more than twice as great with low-volume sprays; and of even greater importance, the persistance of residues can be more than three times as long."

METHODS

Study Area

Fenthion hazards were monitored at two quelea colonies (named Crocodile and Ranch Colonies), 10- and 40-ha in size, located on the >100,000-ha Kulalu Ranch, just southeast of Tsavo East National Park, along the Galana River, Kenya (Coord. 3°05'S x 39°15'E). These two quelea nesting colonies were about 10 km apart (Fig. 1). At least one additional colony was known to exist nearby. Colonies were situated in low (2-3 m) thornbush (mix of *Acacia senegal*, *A. ruficiens*, and *A. mellifera*) along seasonal drainages on a large cattle ranch where there had been no prior use of pesticides. This area, characterized by mixed thornbush and short-grass savanna is a traditional quelea nesting area between November and March (Allan undated); good rains in 1985 prolonged nesting into May. Using procedures described by Elliott (1981), both colonies were mapped and gridded into 0.24-ha quadrats. Quadrats were then sampled to determine vegetation and nest density, percent occupancy of nests (based on the presence of feces), age of colony, and mortality following spraying. Because young had left the colonies before they were censused, the theoretical population in each colony was extrapolated based on two adults and 2.8 nestlings/nest (Morel and Bourliere 1955; Morel and Morel 1974). Birds of prey were present throughout the area. Tawny eagles were especially visible, in flight and perched on the taller trees (*Delonix elata* and *Dobera glabra*) that were scattered through the thornbush. (See APPENDICES I and II for a list of the birds and mammals found in association with these colonies).

Spray Operation

Both colonies were sprayed by DLCO-EA, which regularly sprays quelea colonies in Kenya, Tanzania, Sudan, Ethiopia, and Somalia. The spray

plane was a De Havilland Beaver, fitted with a twin Micronair AU 4000 spray pod system, flying at 167 km/h, with blade angles set to give vmd droplets of 80 micrometers (μm). Total volume sprayed was 40 L and 100 L of Queletox (60% active ingredient [a.i.] fenthion), respectively, in the 10- and 40-ha colonies. Spraying was conducted during about a 10-min period between sunset and dark with the airplane making several passes over each colony in a direction relatively perpendicular to the wind (Fig. 2). Each colony was sprayed once on separate evenings. These were the first spray operations ever conducted in the area and applications were made solely for this study. Control operations generally are not conducted in this area of Kenya because these quelea concentrations are not associated with agricultural areas. Both colonies were sprayed after young had left the nests, but while many were flightless and most were still being fed by adults.

Fenthion deposits in each colony were monitored by three methods. First, three lines of thin-layer chromatography plates were set out at ground level in Crocodile Colony. In both colonies, filter papers also were set out in lines. Each line consisted of 10 plates or papers, 100 m apart, beginning 200 m upwind and running 700 m downwind of the colony center (zero). In the colony center, a second filter paper was placed at ground level and a third at about 4 m in a tree. At Crocodile Colony, one line of plates was picked up at 12 h, another at 24 h, and the third at 48 h postspray. Each plate was analyzed separately for fenthion. At Ranch Colony, all papers were retrieved 14 h after spraying and papers from the same station on each line were composited for analysis. At both colonies, one of a pair of papers at the center of the colony on each transect line was picked up and extracted within two hours of spray applications. Secondly, Teejet(R) CF-1 water- and oil-sensitive cards were put alongside the filter papers on the three transects in Ranch Colony. All Teejet papers were picked up 14 h postspray. The number of droplets in each of five 1-cm^2 units, one at each of the four corners and one at the center of the papers was counted using a Bausch and Lomb scope at 10 x magnification. Droplets < 200 μm dia could not be counted. Thirdly, CF-1 oil-sensitive paper strips were positioned vertically at 0.3, 1.5, and 2.5 m above ground on 3.0-m poles placed at 25-m intervals, in two 200-m sampling lines in open spaces between nesting trees. Deposits on these vertical papers were converted to droplets per cubic centimeter of air to depict droplet densities in the airmass flowing through colonies. Droplet counts at different heights were measured; to provide an indication of drift and the potential for spray to impact young in the bushes or on the ground.

Hazard Assessments

Species counts, radio-tracking, trapping, searches, and bioassay: Stickel (1973) recommended that studies of OP's and carbamates include searches for debilitated and dead birds and analyses of brain tissue or blood to determine cholinesterase inhibition. We included these approaches in our study as well as a variety of other methods to identify the wildlife in the study areas, their morbidity and mortality caused by spraying, and changes in their abundance after spraying. Mist-netting, trapping, and

radiotelemetry were used to monitor occurrence, numbers, activity, and movements of quelea and other nontarget species before and after spraying. Mist-netting also helped to complement our observations and to verify species identification. We made usual counts of raptors; such counts were found by Thiollay (1975, 1978) to adequately census raptors. Common and scientific names of all bird and mammal species observed or collected in the colony areas are given in APPENDICES I and II. Bird identifications were based on a checklist compiled for the area by Lack et al. 1980. In addition, individuals of three species of birds and two species of rodents were identified from skins by personnel at the National Museum of Kenya, Nairobi.

We captured raptors using bal-chatri traps (Berger and Mueller 1959; Berger and Hamerstrom 1962), mist-nets, harnesses attached to live chickens with different test strength monofilament nooses on their backs and hoops and/or heavy cord with monofilament nooses attached to chicken carcasses (APPENDIX III). After capturing raptors, radio transmitters were attached to the dorsal base of the tail feathers using Hotmelt Glue(R) (Fitzner and Fitzner 1977, Bruggers et al. 1981a). Birds were released and radio-tracked before, during, and after each spray application to establish normal movement patterns, determine changes in movement patterns, and to detect any mortality. Quelea, doves, and one Taita fiscal also were mist-netted in the nesting colonies, equipped with radio transmitters, and monitored before and after spraying to determine if they survived treatment.

Because of the possibilities of both primary and secondary hazards to mammalian predators, we captured several mammalian predators in or near colonies for radio-tracking using No. 3 padded coyote traps (Linhart et al. in press) and a variety of fetid scent materials or rancid animal flesh to lure them to the trap. We used a choker-pole or canvas hoop net to restrain these predators at the trap site and transported them in a heavy cloth bag. Ketamine hydrochloride (15 mg/kg) was used to tranquilize some predators while others simply were manually restrained for radio-equipping and taking blood samples. Radio-equipped mammalian predators were released and monitored similar to the radio-equipped raptors.

The utility of radiotelemetry in or for hazard studies is that it allows identification of individual animals that can be located when desired (Hegdal and Gatz 1976; Fagerstone et al. 1980; Hegdal and Blaskiewicz 1984; Hegdal et al. 1986). This permitted us (1) to differentiate between immigration and emigration; (2) to determine the use of contaminated areas by radio-equipped animals; and (3) to determine their fate and to recover any dead animals. All radio transmitters were built by the Bioelectronics Laboratory, DWRC. They were designed to transmit in the 164 MHz band and operated at different pulse rates between 30 and 120 pulses/min. Jackal transmitters weighed 270 g and had a battery life of 1 yr; eagle transmitters weighed 18 g and had a battery life of 3 mo. Both types of transmitters were equipped with mortality circuits that increased the pulse rate to 220-250 pulses/min after a 1-h motionless period. Transmitters used on quelea and other small birds

weighed 1.0-1.3 g and had a battery life of 30 days (Bruggers et al. 1981a). Similar transmitters had been previously used successfully to determine movements of quelea (Bruggers et al. 1983). Mortality circuits could not be added to these transmitters without increasing their weight beyond that which the birds could carry.

Three-element Yagi antennas were employed during all radiotelemetry tracking. A single, hand-held Yagi was used for ground tracking. For aerial tracking, a single Yagi antenna was attached to each wing strut of a De Havilland Beaver aircraft. We attempted to locate radio-equipped animals daily either from the ground or air from the time the transmitters were attached until the study ended. We made 17 flights that usually lasted about 2 h and followed techniques described by Mech (1983) and Gilmer et al. (1981).

Small mammal (rodent) populations were trapped both inside and outside each colony along two parallel 800-m transects before and after spraying for 2 successive nights. Sixty-six traps (22 Victor, 10 Sherman, 22 Museum Special, and 12 Tomahawk) were set each night.

Random searches were made for dead animals 1 day before spray applications and daily for 5 consecutive days starting the morning after spraying. Colonies, and at least a comparable area of surrounding bush that included large trees in which raptors perched, were searched for several hours each day. All debilitated nontarget animals were noted and captured when possible; carcasses were saved for ChE measurements. The rate of carcass disappearance in each colony was determined by placing two dead birds (quelea and other passerines that had been collected for pre-exposure brain ChE levels) at each of 25 locations marked with colored flagging along a meandering 625-m transect. One leg on these birds was marked with colored tape to distinguish them from those dying during the spray applications. The transects were checked for 1 day before and 3 days after spraying.

Habitat Contamination and Animal Exposure

Several materials within colonies were sampled to determine potential levels of fenthion on foods eaten by animals. Samples of dead or dying insects were collected for residue analysis as their contamination constituted a potential hazard to insectivorous birds. A representative sample of dead insects was collected in Crocodile Colony 14 h postspray while walking through the sprayed area. In Ranch Colony, dead and dying insects were systematically collected 14 h after spraying within 0.2-m^2 sampling units that were placed in 100 scattered locations. Grass plants in each colony were collected before spraying and for 3 days after spraying to monitor fenthion residues available to herbivores. In addition, a thin layer of millet seed was exposed on a tarp in the center area of the colony to determine spray contamination on seeds of the sort that might be eaten by birds.

Five or six quelea placed in cages (30 x 30 x 30 cm, constructed of 2.5-cm mesh poultry netting) either on the ground or near the top of a 4-m tree in the center of each colony, and on the ground at 100, 200 and 300 m downwind of both colonies. Cages were picked up 14 h after spraying. The birds were provided water and food, and mortality rates were monitored for 4 days. Brains of birds that died were removed for ChE levels and fenthion residues were extracted from their plumage. In addition, a variety of other animals were exposed to the sprays in the center of the colonies either in cages or by tethering (Table 2). All animals were observed for signs of toxicity for 5 to 7 days. A bias was present as exposed animals were those easiest to capture and maintain. Residues on quelea were of particular interest, as dying quelea represented an abundant food source for a variety of avian, mammalian, and invertebrate predators and scavengers. To determine if fenthion residues on moribund quelea posed hazards to predators and scavengers, between 5 and 15 affected quelea were collected in the colonies at 24-h intervals for 4 days after fenthion application for residue analyses. Brain ChE measurements also were obtained for these quelea to describe the degree to which they were affected by fenthion.

Because of the proximity of the two sprayed colonies and the mobility of birds, only those collected prior to the spray date of Crocodile Colony, 25 April, can truly be considered unexposed and unaffected. However, we did not adhere to this strict interpretation for some bird species, particularly the more sedentary ones, and considered some of them unexposed when collected several kilometers from the colonies after the sprays. We designated birds as affected if they appeared physically debilitated or when they exhibited no overt signs of debilitation, yet had ChE levels that were considerably lower than unexposed individuals of the same species. This was the case when we found clusters of birds with higher levels of ChE compared to clusters of birds of the same species with lower levels.

Analytical Techniques: ChE Determination and Fenthion Residue Analysis

OP's inhibit a number of cholinesterase (ChE) enzymes in animals and, therefore, measurements of ChE activity in brain tissue and plasma can be used to monitor exposure to ChE inhibitors such as fenthion (Grue et al. 1983). ChE levels were measured in most animals trapped, mist-netted, collected, or handled before and after spray to determine if they had been exposed to fenthion. Additional animals were shot to increase sample sizes. Blood samples were taken from animals equipped with radios to establish pre- and postspray ChE levels. Brain ChE levels were determined from insectivorous and granivorous birds collected in and around each colony.

In the field, tissue and blood sera were frozen in liquid nitrogen in Dewar Flasks. They were later transferred to freezers in Nairobi and were analyzed within 1-4 weeks of collection. ChE analyses followed methods described by Hill and Flemming (1982). Brain ChE activity was measured as the micromoles (μmol) of substrate (acetylthiocholene iodide) hydrolyzed per minute per gram of brain tissue at 25°C. In serum, ChE activity was

measured in milli-units (mU). A unit was defined as that quantity of enzyme that converts a micromole of substrate per minute per milliliter (mL) of serum at 25°C.

Fenthion residues were removed from the entire surfaces of quelea, grasses, seeds, insects, and filter papers by placing samples in plastic bottles with known amounts of methanol and shaking for about 5 min. Extracts were returned to the Denver Wildlife Research Center, where residue analyses were conducted. The extracts were stored at 3°C for up to 2 months. Samples were prepared for residue analysis by placing them in warm water (about 60°C) and evaporating the solvent to a volume of 0.5 mL using a gentle stream of nitrogen. Particulate matter was separated by centrifugation. Reference standards were prepared in methanol and stored at 3°C from compounds obtained from the U.S Environmental Protection Agency Pesticide and Industrial Chemicals Repository.

Samples were analyzed for fenthion residues by capillary gas chromatography, using a Hewlett-Packard Model 5890 gas chromatograph and a Hewlett-Packard Model 5970 mass selective detector. The chromatograph was equipped with a fused silica capillary column (0.20 mm i.d. X 12 m) with a liquid phase of cross-linked methyl silicone and a film thickness of 0.33 µm. The injection port was operated at 250°C, and the transfer interface was kept at 280°C. The flow rate of the helium carrier gas was 15 mL/min, measured at 100°C. A splitless (0.7 min) sample injection of about 2 mL was made using a Hewlett-Packard Model 7672A automatic sampler. The initial column temperature of 100°C was held for 1 min, then programmed to 250°C at 20°C/min. Fenthion was quantified using the selected ion monitoring (SIM) mode at a mass-to-charge ratio of 278. The electron impact ionizing voltage was 70 eV. The limit of detection for fenthion was 0.4 µg/mL of sample. Fenthion residues for all samples collected in this study are given in APPENDIX IV.

RESULTS

Colony and Spray Descriptions

Crocodile and Ranch Colonies were sprayed on 25 April and 4 May, respectively. At the time of treatment, Crocodile Colony was well advanced with many young between 35 and 40 days of age and flying among bushes and feeding within the colony. Few adults returned at night to roost with the young in the colony. Ranch Colony was the larger of the two consisting of an estimated 0.5 million adults and 0.75 million young (Table 3). Young in the colony were of two ages, as a 10-ha portion of the colony appeared to have been established about 27 March and the remaining 30 ha on about 4 April. Young from this later nesting attempt were just out of the nest and very susceptible to predation. We estimated an additional 1.0 to 1.5 million adults and young roosting within Ranch Colony on the night of the spray. These birds evidently were from other recently completed colonies in the vicinity. Both sprays resulted in large numbers of dead and dying queleas. Young in Crocodile Colony began dropping from the bushes in large numbers by mid-day of 26 April, and

affected birds were observed on the ground under nesting trees for 4 days following the spraying. In Ranch Colony, many dead and dying queleas were found the morning following treatment and for up to 7 days thereafter.

Spray Deposits

Filter papers placed at the three stations in the center of Crocodile Colony had deposits equal to 213, 24, and 52 g/ha of fenthion immediately after spraying. Papers in the center of Ranch Colony had residues of 109, 524, and 149 g/ha shortly after spraying. Deposits were not uniform, reflecting efforts of the pilot to apply fenthion to moving concentrations of birds (the recommended spray procedure for quelea control) and did not try to treat the colony uniformly. The highest residues were found at Ranch Colony. Differences in deposits may have been due to windspeed, which was much higher at Crocodile Colony. Residues at both colonies immediately after spraying suggested less than 10% (g/ha on filter papers ÷ g/ha from plane) of fenthion sprayed actually was deposited on the ground. Although some spray particles were deposited on bushes and trees, considerable amounts must have been carried away from the colonies on air currents.

Papers collected 12 h postspray in Crocodile Colony indicated residues were heaviest in the center of the colony, and were greater on the ground than 3 m above the ground in a tree (Fig. 4). Residues were much lower upwind and downwind from the colony, except at 200 m downwind, where heavy deposits occurred. In general, residues were only one-tenth as great as immediate postspray residues by 24 h postspray and even less after 48 h. A rapid degredation of fenthion residues was indicated, probably due to heat and sunlight (Metcalf et al. 1963).

At Ranch Colony, initial fenthion residues were greater, and residues were higher after 14 h than they were in Crocodile Colony after 12 h (Fig. 3). At Ranch Colony, deposits were heavy from 200 m upwind to 200 m downwind of the colony center. As this was a larger and wider colony, it is probable that the pilot applied fenthion over a 400-m wide area as he sprayed the milling quelea. Residues at 300 m downwind and beyond were much lower than in the colony center, but still were twice those at Crocodile Colony. As in Crocodile Colony, deposits at the center of Ranch Colony were greater on filter papers placed on the ground than on papers placed inside tree canopies.

Calculated droplet densities and droplet counts on spray cards gave additional evidence on the pattern of fenthion deposits within colonies and throughout adjoining areas (Tables 4 and 5). Droplet counts on spray cards at ground level were higher at colony center than downwind. Although cards were placed next to filter papers at each location, droplet counts and residue analyses did not always give comparable results. While fenthion residues on filter papers were lower at 100 m downwind than at 200 m downwind (Fig. 4), droplet counts on all transects were lower at 200 m than at 100 m downwind (Table 4). Also, droplet counts indicated deposits were greater in trees than on the ground, whereas residue levels were greater on the ground than in trees.

Droplet densities (no./cm^3 of air), calculated from deposits on vertical spray cards, increased with height above ground and were greater at 75-150 m downwind than at colony centers (Table 5). These results suggest many of the spray droplets were suspended in air moving through the colonies, which is where they have the greatest probability of impinging on quelea. As with residues and spray droplets measured at ground level, droplet densities suggest much of the fenthion applied was carried in air away from the colony.

Fenthion Contamination and Effects in the Environment

Massive numbers of young quelea were killed by treatments. In Crocodile Colony, young were not affected until about 20 h postspray. In Ranch Colony, the ground under nest trees was covered with affected and dead young the morning after spraying, only 12 h postspray. Young were found dead in an area of about 11 and 35 km^2 surrounding Crocodile and Ranch Colony, respectively, for 4-7 days postspray. Residues washed from the feathers of debilitated birds collected in Crocodile Colony the day after spraying were quite variable, ranging from 11 to 115 µg with a mean of 44 µg of fenthion per bird. Debilitated young in Ranch Colony collected the morning after spraying carried even higher residues averaging about 84 µg (Table 6).

In both colonies, fenthion residues on young quelea were much lower on subsequent days; but even after 4 days, levels still averaged 12.0 µg on young in Ranch Colony. There are two possibilities for these findings. Residues on living birds undoubtedly decreased over time as fenthion decomposed. However, it may also be that birds with high residues died quickly and birds alive after 2 to 3 days had initially received less exposure and survived longer. Actual death of the latter birds may have been caused initially from a lack of feeding and ultimately from starvation because many of the adults had been killed by the treatment. Pope and Ward (1972) found quelea treated with more than 0.03 cm^3 Queletox (18.0 µg fenthion) died immediately. Birds treated with 0.001 cm^3 Queletox (0.6 µg fenthion) or less died slowly over 48 h, which they suggested was from starvation. However, in both situations it is possible that residues absorbed by these birds affected them, rendering them too weak to feed.

Fenthion had a particularly striking effect on insects. Dead and dying insects were present throughout both colonies on the morning after fenthion applications. By the second day postspray, however, some insects were again seen flying in colonies. For collections of dead insects from Crocodile Colony, residues were highest on members of the family Gryllidae. Topical residue levels on dead insects collected in Ranch Colony 18-24 h after spraying were variable (0.0 to 23.0 µg), but fenthion was found on 25 of the 27 samples (Table 7). The highest residue level (23.0 µg) was found on a sample of carabid beetles, but residues of 0.89 to 11.0 µg found on samples of Orthopterans were consistently higher than residues on most other samples. Adequate scales were not available to weigh individual samples of insects and spiders, but the total weight of all individuals in the 15 samples from Ranch Colony was 8.5 g, and in the aggregate, those samples contained 61.3 µg of fenthion.

Within colonies, fenthion residues on grasses were high on the first day postspray (Table 8). Grass samples had residues as high as 38 ppm, which could be hazardous to herbivores if consumed over a number of days. For instance, the LC_{50} of fenthion to bobwhite quail (Colinus virginianus) over 5 days is 30 ppm (Heath et al. 1973) and exposure of mallards (Anas platyrhynchos) to 0.5 ppm fenthion was lethal to some birds in 30 days (Hudson et al. 1984). However, residues on grasses decreased rapidly and were below 2.0 ppm on the third and fourth day postspray. Apparently, high temperatures and sunlight rapidly decomposed fenthion residues. Residues from the sample of millet in the center area of Crocodile Colony were contaminated with 1.1 ppm fenthion, and therefore, contaminated grass seed in colonies could present some hazard to seed-eating birds if residues persisted.

Exposure of Caged Animals to Spray Applications

No mortality attributable to fenthion occurred in any of the caged animals (other than quelea) that had been placed in the colonies. Based on these exposure trials, ChE levels from harlequin quail collected postspray and other observational evidence, most gallinaceous birds did not appear affected by fenthion sprays. We did, however, find six button quail that were sufficiently debilitated to be hand captured. However, the bottles containing their brains broke in the Dewar Flask and the samples could not be analyzed for brain ChE activity.

All but two caged quelea exposed in colonies died. Those exposed in Crocodile Colony (Table 9) died sooner than those exposed in Ranch Colony (Table 10), even though higher spray deposits were present in the center of Ranch Colony (524 g/ha) than in Crocodile Colony (213 g/ha). In Crocodile Colony, quelea from the center area and 100 m and 200 m downwind all died within 24 h. Only one of the birds exposed 300 m downwind had died after 24 h; it took 48 h for all birds to die. This further demonstrated that fenthion can kill slowly and that birds that appear healthy after exposure to fenthion may later succumb to either its direct or indirect effects.

Quelea exposed in Ranch Colony on the ground at the center, and 100 m and 200 m downwind all died within about 48 h. Spray-card deposits and residues indicated they were exposed to more fenthion at those locations (Table 4; Fig. 4). Birds exposed in a tree at the center of the colony died more slowly; the last debilitated bird died on the fourth day after spraying, a time comparable to the death of sprayed young in the colonies. Although spray-card deposits were heaviest in trees, residues on filter papers were lower in trees than on the ground. Regardless of these inconsistencies, the spray apparently did not affect caged birds in trees as quickly as those on the ground.

Exposure of Radio-equipped Animals

We captured and radio-equipped 11 tawny eagles, 3 bateleur eagles, 4 pale chanting goshawks, 2 gabar goshawks, 2 pygmy falcons, and 2 pearl-spotted owlets (Table 11). We also captured, radio-equipped, and

took blood samples from eight mammalian predators including seven black-backed jackals and one common genet (Table 12). A bat-eared fox was captured and a blood sample taken, but it was not radio-equipped. Many of these birds and mammals were monitored during the first 2 weeks after Crocodile Colony was sprayed and for 4-8 days after fenthion was applied to Ranch Colony. None were known to have died, but several became debilitated from fenthion poisoning. Individual movements of radio-equipped birds are given in APPENDIX V.

Twenty-three of 33 radio-equipped animals were located postspray in a colony or in the area around a colony where dying, contaminated quelea were found (Fig. 5). One radio-equipped pearl-spotted owlet was found dead prespray, apparently having died from a capture-related injury. The other pearl-spotted owlet was found moribund 1 day postspray and was collected. Its brain ChE activity was 6.3 μmol/g.

One radio-equipped tawny eagle (No. 2) was debilitated when captured 3 days postspray; it was held overnight and then released. It was captured again in poor condition on the day it was released and was killed to obtain blood and brain samples for ChE measurements. Nine of the remaining 10 tawny eagles were located at least once postspray in an area with dead and dying quelea. Tawny eagles No. 5, 9, and 10 apparently fed in or near both colonies postspray; No. 9 and 10 even fed in the third colony in the area that was not sprayed as young became available.

Only 1 of 3 (No. 3) bateleur eagles was known to be exposed to dead and dying quelea. All four pale chanting goshawks (Nos. 1-4) foraged in and near areas with dead and dying quelea. Also both gabar goshawks and both pygmy falcons foraged in and near areas with dead or dying quelea postspray.

We lost contact with the common genet and one radio-equipped black-backed jackal after instrumentation. Three (Nos. 2, 3, and 6) of the other six jackals were never located in an area with dead and dying quelea postspray. The remaining three jackals (Nos. 4, 5, and 7) were located in areas with dead and dying quelea postspray and probably fed on them.

The results obtained from 24 other radio-equipped birds, including 1 Taita fiscal, 3 doves, and 20 adult quelea are summarized in Table 13. The fate of most of these birds is unknown because of the absence of mortality sensors in their transmitters. We lost radio contact with the taita fiscal soon after instrumentation. Two doves left the general vicinity immediately while the other laughing dove (No. 2) was tracked near areas of dead and dying quelea postspray and may have been killed by the spray.

In Crocodile Colony, we radio-equipped 11 quelea 2 days before spray application. Transmitters from two of those quelea were recovered in acacia bushes prior to spraying, having come off of birds. One quelea was last located about 30 km south 1 day postspray. Two other quelea were last located in or near the colony the day after spraying, and most likely

were dead. Six other quelea were tracked 5-11 days postspray, generally southwest of the colony, and were not located in the spray area posttreatment. Since they were not relocated after 11 days, they probably left the general area, or their transmitters may have failed.

In Ranch Colony, we radio-equipped nine quelea prior to treatment; six 6 days prespray and three 2 days prespray (Table 13). We lost radio contact with two of these quelea almost immediately after instrumenting them (Nos. 12 and 13). Three others (Nos. 14-16) were tracked for only 1 or 2 days prespray and probably left the area before the spray. The transmitter for No. 17 was found in the colony, off of the bird, 5 days postspray; this bird may have been sprayed and then been eaten by a scavenger. We tracked the remaining three quelea (Nos. 18-20) from this colony for 5 to 6 days postspray, during which time all three were tracked in the sprayed area. One, No. 20 was in the Ranch Colony during the spray application. All three apparently died from exposure to fenthion.

Cholinesterase Levels in Birds and Mammals

Brain levels of ChE were quite variable in quelea caught in mist nets before spraying of Crocodile Colony. ChE activity averaged 47 $\pm$ 11 µmol/g (range 35-61) for adults and 42 $\pm$ 5 µmol/g (range 38-56) and were not significantly different ($P > 0.05$) (Fig. 6). Brain ChE levels in flightless young picked up alive under nest trees in Crocodile Colony during the first 4 days postspray averaged 12 $\pm$ 5 µmol/g (range 5-28), which was significantly less ($P < 0.05$) than levels in prespray young. One young on each of day 2 and 4 postspray showed higher ChE activity of 25 and 28 µmol/g, respectively, which suggested they had received considerably less exposure than other individuals. Flying young mist-netted in Crocodile Colony 3 days postspray had from 12.7 to 35.5 µmol/g of ChE activity in brain.

Adult quelea exposed in cages to fenthion applications in colonies showed variations in effects that appeared related to the location of cages (Fig. 6). Birds exposed in cages in the center of Crocodile Colony and 100 m and 200 m downwind had reduced ChE activity in brain (10.9, 12.9, and 16.1 µmol/g, respectively), and all died within 24 h even with food and water.

Some inconsistently high ChE levels found in a few birds are of interest. A single debilitated young quelea collected on day 2 and another on day 4 after spraying had much higher ChE levels than other young (Fig. 6). Two quelea caged in a tree at the colony center did not show much ChE depression (26.9 and 37.2 µmol/g), but both had died within 20 h of exposure. Four of the five birds in a cage at 300 m downwind from the center of Ranch Colony showed ChE depression, but only three of the five died. For adult quelea it appeared that ChE activity levels in brain below about 20 µmol/g were indicative of fenthion exposure and those below about 15 µmol/g were associated with death of birds. It should be mentioned that quelea are easy to maintain in captivity (Pope and Ward 1972), and death should not be expected in birds provided with basic necessities.

Three tawny eagles (Nos. 9, 10, and 11), captured before the first fenthion applications, were the only raptors known to be free from exposure to fenthion. These eagles had ChE activity levels in blood of 1416, 1418, and 1437 mU/mL. As eagles can move considerable distances, any of those in the general area could have received exposure after fenthion was first applied. Of seven tawny eagles from which blood samples were taken after spraying was begun, five had blood ChE activity below 900 mU/ml and probably were exposed to fenthion (Fig. 7). Only two of the five appeared affected. However, one eagle that was collected in Ranch Colony and appeared physically normal contained five young quelea and had the lowest ChE activity in both blood (136 mU/mL) and brain (7.6 µmol/g) of any eagle examined. Brain ChE activity in two other debilitated eagles was below 10 µmol/g, and their survival was questionable. Based on the number of tawny eagles in the area, it is probable that many others had been similarly exposed.

Three bateleur eagles were captured after spraying was begun. They did not appear to have been affected by fenthion as their ChE activity in blood was among the highest measured in any raptor (Fig. 7). A sick pygmy falcon observed eating dead quelea had ChE activity of 623 mU/mL in blood and 7.1 µmol/g in brain. A male and female pygmy falcon who were evidently mated had similar ChE activity levels in blood (888 and 661 mU/ml, respectively) and probably had been exposed to fenthion. A fourth pygmy falcon examined had ChE activity in blood of 1264 mU/mL. Although it was captured near Crocodile Colony after fenthion applications, it apparently was not exposed.

A pale chanting goshawk observed eating dead quelea had the lowest ChE activity in blood (513 mU/mL) measured for this species. Two others examined had only slightly higher levels (627 and 785 mU/mL), which were similar to levels found in two gabar goshawks (632 and 663 mU/mL). All five goshawks were regularly located in the colony areas and undoubtedly had been exposed to fenthion. A single pearl-spotted owlet found moribund had ChE activity in brain of 6.3 µmol/g, also suggesting exposure to fenthion (Fig. 7).

ChE activity in blood of raptors below 900 mU/mL seemed to indicate fenthion exposure, and this in turn suggested that 16 of 22 raptors examined after spraying were affected by the sprays. All of these were alive when first seen, and none were known to have died during the time of this study. However, M. Jaeger (pers. obs.) and S. Thomsett (pers. obs.), both of whom have tried to revive sick raptors found after fenthion control operations, have indicated that once raptors show signs of toxicosis following exposure to fenthion, they do not recover.

From 1 to 15 individuals of 21 other bird species were collected for ChE analysis before and after fenthion spraying. Most were caught in mist nets, a few were shot, and other debilitated birds were captured by hand. Forty-four individuals of 17 species were found debilitated during 71 man-hours of searches in or near colonies after fenthion application (Table 14). Based on the date and location of capture and the habits and range in movements of the species, it was known that many were not exposed

to fenthion. Some birds caught in or near sprayed areas may or may not have been exposed. Still others were clearly in situations where they would receive exposure to fenthion. In an attempt to help interpret ChE measurements, each bird examined was designated either as exposed, unexposed, or as unaffected if exposed.

Levels of ChE activity in brains of birds showing no apparent ChE depression are shown in Figure 8. For these species, all values of ChE activity tended to cluster around values determined for unexposed birds. A harlequin quail apparently was debilitated by causes other than fenthion, as its ChE activity was the highest of those measured for the species. Even quail and doves exposed to fenthion in cages were not overtly affected and appeared to have normal ChE levels. In contrast, Figure 9 shows that ChE measurements in many other species were lower in exposed than in unexposed individuals. In most species, sick individuals collected had low ChE activity in brain. For the species tested, ChE activity of about 20 µmol/g and lower suggested exposure to fenthion, while most debilitated and moribund birds had levels of 10 µmol/g or less.

Because we were able to analyze only a few mammals, the data are inconclusive. An African false vampire bat captured before any fenthion applications had a ChE activity in brain of 21.8 µmol/g, while two other African false vampire bats captured in colonies after treatments showed levels of 16.6 and 17.5 µmol/g of ChE activity. A single black-backed jackal captured after spraying had 13.3 µmol/g ChE activity in brain. ChE levels in rodents trapped in the colonies were not determined because of their scarcity in and around colonies (Table 15) and our emphasis on evaluating the more sensitive avian species.

Disappearance Rates of Dead Birds

The 44 debilitated or dead nontarget birds found during postspray searches would seem to suggest that a relatively large number of birds was affected. The dense grass probably hid many smaller birds, and scavengers removed many more. We began finding dead and debilitated birds the morning after each spray. Black-backed jackals were abundant in the area and likely were the principal mammalian scavenger. Besides bat-eared fox and common genet, we saw dwarf mongooses and baboons feeding on quelea and also heard spotted hyenas in the area; all of these animals commonly scavenge in quelea colonies. In addition, a variety of birds of prey and dung beetles were observed eating dead birds in the colonies.

If the rate of disappearance of the dead birds placed along transect lines in each colony is an accurate indication of the removal rates in the colonies, between 24 and 90% of the moribund or dead animals can be removed by these scavengers just during the 15 h immediately postspray (Table 16). Despite the availability of large numbers of dead and debilitated quelea, we have no reason to suspect selective scavenging of nontarget species. Predators removed 96% of 23 quelea corpses and 85% of 27 nontarget corpses that had been placed along the transect line in Crocodile Colony during the first night. Such rates are slightly higher

than those found by Bruggers et al. (1981b) in a roost in Somalia. In that study, scavengers took 62% of dead quelea placed in the roost the first night and had eaten 100% of the birds by the third night. These disappearance rates support the conclusions of Rosene and Lay (1963) in their quail study that predation rates on dead birds can be high and that finding even a small or moderate number of nontarget birds is reason to suspect a rather heavy mortality.

DISCUSSION

Quelea Mortality

Fenthion was especially effective in killing quelea. In colonies most young, flightless quelea were affected and fell to the ground beneath the nesting trees. Many adults also were affected and many were found outside of the colonies in an area of at least 35 km^2 around Ranch Colony. Both debilitated adults and young continued to die for up to 7 days. Thomsett (pers. comm.) observed quelea dying for up to 19 days following the previously mentioned roost control operation in 1984 in Kenya when a ground sprayer and low-volume techniques were used.

Quelea are said to die within 24 h when deprived of food (Pope and Ward 1972). Young birds often have the ability to withstand periods of starvation. They cease to grow or develop when not fed, which is an adaptation for survival during temporary food shortages. Pope and Ward (1972) also showed that quelea survived longer as their exposure level to fenthion decreased. It is possible that not all birds were exposed to fenthion to the same degree. Variation in exposure was suggested in the caged adults. Adults exposed in trees showed less ChE inhibition than birds exposed on the ground. Even birds in the same cages showed large variations in ChE inhibition, presumably because some birds were covered by others as they huddled in the corners of the cages. Factors such as droplet size, relative deposits of spray at different heights above the ground, vegetation canopy, and behavior or relative activity (excitability) of birds during applications might account for differential exposure of individuals. There is some indication that young quelea are more difficult to kill than adults during sprays with fixed-wing aircraft, as they usually stay in the bushes, whereas adults tend to fly through the spray (M. Jaeger, pers. obs.). C. Elliott (pers. obs.) has had better success spraying young birds when using helicopters, evidently due to the downwash effect, which may permit spray droplets to better penetrate the canopy. This effect would also account for the lower exposure of the adults caged in trees compared to those caged on the ground.

Fenthion residues on young quelea under nest trees averaged 44 µg in Crocodile Colony, and 84 µg in Ranch Colony on the day after spraying. This finding seems consistent with our having found many more affected birds in the morning postspray in Ranch Colony than in Crocodile Colony. However, average residues of fenthion on the feathers of young quelea were lower each succeeding day after spraying. It is not clear if this was due to fenthion degredation over time or if it reflected that birds receiving less exposure survived longer, or both.

Young quelea collected on the ground below nest trees also had greatly reduced ChE activity in their brains, but many survived for more than 4 days postspray. Most quelea collected after spraying showed similar ChE activity in brain, but each day after spraying, fenthion residues on their feathers had decreased. Although all young apparently died, it is not clear why it took them so long to do so. Their ChE activity in brain averaged about 10 µmol/g, which is 75% less than the 40 µmol/g measured in eight unexposed young (Fig. 6). Most studies suggest ChE inhibition of about 70% can be expected in birds that die of organophosphate poisoning; however, it is possible for some individuals of some species that show equal or greater inhibition to survive (Hill and Fleming 1982). Recovery of normal ChE levels in affected birds can occur, although it can require up to 30 days (Grue et al. 1983).

It seems strange young quelea survived so long without food and water, especially with greatly reduced ChE levels. Pope and Ward (1972) stated that in routine spray operations, using existing techniques, the birds die in under 12 h. However, at that time, application rates were greater and fenthion was applied in diesel oil (Anon. 1979). Jaeger (pers. obs.) also has observed birds dying in <12 h following sprays with application rates similar to those used in our study, when fenthion was also mixed in diesel oil and sprayed to give droplets of 100-200 µm.

Impact on Raptors

No dead eagles were found during this study, but seven sick or affected (reduced ChE activity) tawny eagles were found. Bateleur eagles did not appear debilitated or affected. One pygmy falcon and one pearl-spotted owlet were found sick, while three of four pygmy falcons, three pale chanting goshawks, two gabar goshawks, and a single pearl-spotted owlet had what was considered to be reduced ChE activity levels in their blood or brain. Of 22 raptors examined after spraying, 16 had depressed ChE levels, while 6 appeared normal. We observed as many as 30 eagles flying, perching, or feeding in or near a colony at a given time. Between 75 and 100 eagles were probably within foraging range of the treated colonies following the sprays. Such concentrations of eagles have been observed following other bird control operations (Thiollay 1978; Thomsett 1984). Most raptors in our study could have been seriously exposed to the sprays, as radiotelemetry data indicated that some raptors, especially tawny eagles and pale chanting goshawks, seemed to concentrate their foraging activities within treated colonies, and some tawny eagles, in particular Nos. 9 and 10, even moved from Crocodile to Ranch Colony, after it was sprayed (Fig. 5) and later to the third unsprayed colony in the area. Others, such as bateleur eagles, seemed to roam more widely for food.

About one-half of the 21 other species of birds collected were subjected to fenthion exposure by spraying the quelea colonies. In species exposed, about 25% of the individuals suffered either serious ChE depression, debility or death. Even though birds are more sensitive to fenthion than mammals, mammalian predators certainly were exposed by consuming dead and dying quelea. Jackals in particular were primary predators of debilitated quelea postspray.

Fenthion has many other influences on the physiology of animals. Grue et al. (1983) have reviewed the hazards of organophosphates to wildlife and cite studies showing the following sublethal effects in birds: reduced egg production, anorexia, loss of body weight, reduced growth of altricial nestlings and weights at fledging, made alterations in the changed production and structure of songs used in territory defense and courtship, visual acuity, vigilance, food-seeking behavior, ability of adults to care for young, reduced time spent on incubation, fewer trips to feed young, reduced nest attentiveness, reduced immune response, decreased ability to learn, decreased hypothermia, and increased susceptibility to predation. Eastin et al. (1982) showed avian salt gland activity was inhibited by fenthion, and this might be an important sublethal effect on raptors in drier areas of Africa. However, the long-term, sublethal effects of cumulative exposure, such as raptors might receive, are unknown.

Although some raptors, and particulary owlets roosting in Ranch Colony, may have actually been sprayed by fenthion, most raptors such as eagles, goshawks, and falcons undoubtedly received their greatest exposure to fenthion from eating affected quelea soon after spraying. We are unaware of any studies of the LD_{50}'s of fenthion to the raptors observed in our study (or to many other species of raptors), but its acute oral toxicity to sparrow hawks (Falco sparverius) and probably most other hawks is 1.3 mg/kg (Schafer 1972). If ingestion of about 1.0 mg/kg fenthion is sufficient to kill some raptors and debilitate others, then young quelea coated with 50.0 µg of fenthion pose a hazard to these birds. Tawny eagles (2.0 kg) would receive a 1.0 mg/kg dose upon eating 40 quelea (2.0 µg fenthion), while a pale chanting goshawk (600 g) would need to eat 12 quelea, and a pygmy falcon (60 g) only 1.2 quelea to receive such a dose. It would require only one-half as many quelea to provide lethal doses if each carried 100 µg of fenthion. Many young quelea carried as much as 100 µg on the day after spraying, but not thereafter. These rates of quelea consumption are realistic and can be expected. Thiollay (1975) has found dead eagles in colonies following sprays with parathion with 16 young quelea in their stomach. He also reported that eagles normally will eat 30 to 40, 4- to 8-day-old quelea each day (Thiollay, in press).

In our study, eagles and other raptors would have received severe exposure only on the first day following application of fenthion. Residues on live, affected quelea decreased rapidly, and raptors would have had to eat greater numbers of young to receive serious exposure even a day or two later. This suggests that when fenthion is used to kill quelea, predators should be kept out of colonies for at least the first day postspray, which might be difficult because of the abundant food source.

Of caged birds exposed in colonies to spray applications, only quelea were affected. Doves, quail, sandgrouse and domestic chickens showed no signs of illness or intoxication and none died following exposure. Likewise, quail that we assumed were exposed to the sprays and that were collected in colonies after spraying showed neither debility nor ChE depression from fenthion exposure. Jackson and Park (1973) also noted that they did not find any dead helmeted guinea fowl (Numida melaegris),

another numerous gallinaceous species, following fenthion sprays in Chad. However, these results were not expected as North American species of doves, pigeons, and quail are highly sensitive to acute oral doses of fenthion which they might obtain from eating contaminated seed (LD_{50}'s of 2.5, 4.6, and 10.6 mg/kg, respectively; Hudson et al. 1984).

Spray Deposits

It is obvious that aerial applications of fenthion will contaminate sprayed areas with fenthion residues. Deposits of up to 500 g/ha were measured in the center of Ranch Colony immediately after spraying, but levels were much lower within the general colony area (24-213 g/ha). By the morning after spraying, residues on cards within the colony and 100 and 200 m downwind had decreased to between 7.1 and 146 g/ha. Residues continued to decline rapidly during the first day postspray and thereafter. At 300 m or more downwind, initial deposits of fenthion were low and again rapidly degraded. Fenthion is highly susceptible to oxidation and, in the presence of sunlight and air, is known to be rapidly transformed into its sulfoxide and sulfone metabolites, which in turn are quickly decomposed (Metcalf et al. 1963).

Fenthion residues of 17 to 38 ppm were found on grasses collected the first day postspray and were high enough to be of concern. However, residues degraded rapidly, so that a sample collected on the fourth day after spraying contained only 1.1 ppm of fenthion. With such rapid degradation of fenthion, contamination of forage eaten by wildlife and livestock should not pose a long-term problem in quelea control operations.

Impact on Insects and Insectivorous Birds

As fenthion usually is used as an insecticide, it is not surprising that applications to colonies killed many insects. Fenthion is not a selective insecticide; mortality was found in 14 families of insects and in spiders. The insect kill was heavy, and based on the lack of ants and flying insects on the day following applications, it was rather complete. Residues on insects varied among families with highest levels present on members of the families Carabidae, Acrididae, Gryllidae, Tetigoniidae, and Mantidae. These residues probably were the source of exposure to the affected insectivorous birds.

Fenthion residues on dead and dying insects represented a hazard to insectivorous birds feeding on them. If the lethal dose of fenthion to a 25-g insectivorous bird was about 2.5 mg/kg, then it would be killed by eating a meal of insects contaminated with 62.5 µg of fenthion. This is nearly the exact rate at which insects were topically contaminated in our colonies. The 8.5 g of insects collected in Ranch Colony contained 61.3 µg of fenthion. A 25-g bird would readily consume 8.5 g of insects, especially debilitated ones that are more easily captured. Most insectivorous birds would be expected to consume at least one-third their body weight each day, and in doing so on the day after spraying would receive a fenthion dose of about 2.5 mg/kg.

CONCLUSIONS

Primary concern of low-volume fenthion application for quelea control must be over its effects on predaceous and insectivorous birds. Fenthion applications caused massive mortality to quelea and insects and brief exposure of birds feeding on quelea or insects to potentially harmful residues. Most granivorous species of birds (other than quelea) apparently were not affected and no evidence of significant effects on mammals was found. Environmental and food chain contamination was brief.

Mortality of raptors and other predaceous avian species due to fenthion sprays must be avoided. Our radiotelemetry data show that raptors are highly mobile, are attracted to sprayed quelea colonies, and will sequentially predate colonies as the availability of young increases. In this manner, they are likely to suffer increasingly greater ChE depression and ultimately death. Many of the raptor species associated with quelea colonies are resident, and mortality could result in severe reductions in local populations. Other raptor species are migratory and only winter south of the Sahel. Thus, the effect of fenthion on the overall populations of migratory species that suffer mortality before they migrate may not be as readily evident. As both resident and migratory raptors are long-lived and generally exhibit a low reproductive rate, they have a greater potential for population reduction than nonpredaceous species.

The number of predators in colonies or attracted to quelea colonies is extremely variable (Thiollay, pers. comm.). Compared to many other colonies we have observed, these two colonies did not attract particularly large numbers or a great diversity of avian predators. Greater numbers regularly can be seen in colonies in Tsavo West (Allan, pers. comm.) and have been observed in colonies in Mali (Thiollay 1975), in Sudan (in the agricultural area of Gedarif/Jebil Sim Sim), and in Ethiopia (Bruggers and Jaeger, pers. obs.). Storks (particularly Marabou storks), egrets, and numerous species of migratory raptors have wrecked havoc on nestlings and young in these and other situations (and have been found dead in colonies following sprays).

Debilitated and dead nontarget bird species can be expected during quelea control operations when using low-volume fenthion applications, as the bush savanna ecosystem supports a large number of bird species. Morel and Morel (1978) recorded 112 species (not including Accipitridae and Falconidae) in an area of only 25 ha in northern Senegal over an 8-year period. We tallied 94 species during our 4-week study. Based on our pre- and postspray observations, it is evident that numerous species of insectivorous and granivorous birds are present in or associated with quelea colonies during lethal control operations. That affected birds are not commonly found following control operations can be attributed to a lack of searching for them and to their removal by scavengers as they die over a period of several days. Casual walks through colonies following sprays without finding dead nontarget animals does not mean that they do not exist. When an effort is made to look for nontarget species, they generally can be found. C. Elliott (pers. comm.) found dead individuals

representing 25 bird species following a spray in Tanzania when villagers searched a large colony. Likewise, on most occasions, time and logistic constraints do not permit personnel conducting control operations to adequately assess postspray mortalities, other than for quelea. For example, the Tanzania National Bird Control Unit sprayed 13 quelea roosts or colonies totaling at least 165 ha between March 21 and April 3, 1980, and 20 more between April 21 and 30, totaling 341 ha (Beesley and Mrema 1980). With limited manpower, such an itinerary does not permit much more than organizing the spray operations.

Nontarget hazards should be an important consideration when developing spraying techniques. It has been assumed that lower spray rates would reduce hazards to nontarget species. This assumption may be invalid, as there may be a point where low application techniques may actually increase environmental hazards. For this reason, efforts to continue to reduce spray quantities and further develop low-volume ground sprayers, which emit even smaller droplets, should be thoroughly evaluated before being recommended for general use. Perhaps chemicals or application rates that kill quelea more rapidly in the nesting colony area, and thereby reduce both the time and area of exposure of dead quelea to predaceous species, should be investigated. The cost of additional amounts of chemical relative to the total cost of a spray operation would be minimal.

Finally, perhaps the two most difficult questions to answer are what is significant nontarget mortality in comparison to the total population of each species in the area, and what is the value of a raptor or other nontarget species relative to protecting cereal crops? These questions need to be considered carefully by individuals and organizations involved in protecting cereal crops from quelea but must be considered in the context of their having to regularly face food shortages. However, assuming lethal control will continue for the present time, it would seem appropriate to initiate greater selectivity in target selection.

RECOMMENDATIONS

Because the behavior of birds, their sensitivity to fenthion, and its action and persistence can vary with season and environmental conditions, additional studies will be necessary to fully understand the hazards fenthion poses to nontarget animals. Assuming the trend to low-volume spray techniques continues, studies similar to the one we are reporting on here need to be replicated either with fenthion or any other chemical being considered. Any number of areas can be looked at in more detail, but the following should be stressed:

1. Conduct laboratory studies of oral and dermal sensitivity of fenthion to wildlife generally found in or associated with quelea nesting habitat.

2. Evaluate droplet sizes and application rates relative to immediate mortality of quelea, their dispersal, and potential impact on quelea.

3. Compare sprays of roosts using ground sprayers and aerial application techniques.

4. Compare the stage of colony development (incubation vs. fledging) when sprayed with the nontarget hazard risk.

5. Analyze more thoroughly the spray effects on insects and mammals.

6. Evaluate the effectiveness of hazing predators or scavengers from contaminated areas.

7. Develop a system to predict the potential impact of sprays on nontarget wildlife in different spray situations.

These kinds of evaluations will be expensive and require enormous logistical support and coordination, but hopefully, can lead to reducing the hazards associated with lethal control of quelea concentrations.

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Table 1. Acute oral (unless dermal toxicity is indicated) toxicity of fenthion to several species of birds and mammals.

Species		LD_{50}		
Common name	Scientific name	(mg/kg)	95% CL	Source
	BIRDS			
California quail	*Lophortyx californica*	15.0	11.9-18.9	Hudson *et al.* 1984
Japanese quail	*Coturnix coturnix*	10.6	8.4-13.3	Hudson *et al.* 1984
Ring-necked pheasant	*Phasianus colchicus*	17.8	9.3-34.0	Hudson *et al.* 1984
Chukar partridge	*Alectoris graeca*	25.9	15.8-42.7	Hudson *et al.* 1984
Rock dove	*Columba livia*	4.6	3.2- 6.6	Hudson *et al.* 1984
Rock dove	*Columba livia*	1.8	1.0- 3.2	Schafer 1972
Mourning dove	*Zenaida macroura*	2.5	1.3- 5.0	Hudson *et al.* 1984
Black-billed magpie	*Pica pica*	5.6	3.2-10.0	Schafer 1972
American kestrel	*Falco sparverius*	1.3	-	Schafer 1972
Golden sparrow	*Passer luteus*	1.3	-	Anon. 1979
European starling	*Sturnus vulgaris*	5.3	3.0- 9.5	Schafer 1972
House sparrow	*Passer domesticus*	22.7	14.6-35.1	Hudson *et al.* 1984
House sparrow	*Passer domesticus*	5.6	3.2-10.0	Schafer 1972
House sparrow (dermal)	*Passer domesticus*	2.4	-	Schafer *et al.* 1973
Red-billed quelea	*Quelea quelea*	1.3	-	Schafer *et al.* 1973
Red-billed quelea (dermal)	*Quelea quelea*	1.8	-	Schafer *et al.* 1973
Red-winged blackbird	*Agelaius phoeniceus*	1.8	1.0- 3.2	Schafer *et al.* 1973
	MAMMALS			
Rat (M) (dermal)		330	-	Anon. 1979
Rat (F) (dermal)		330	-	Anon. 1979
Rabbit (M) (dermal)		150	-	Anon. 1979

Table 2. Numbers of animals exposed in cages during application of fenthion to quelea colonies.

Species, location	Colonies	
	Crocodile.	Ranch
Laughing doves		
Center	3	3
50 m north	2	3
50 m south	2	-
Harlequin quail		
Center	3	3
Domestic chickens		
Center	2	-
Sandgrouse		
Center	1	-
Quelea (adults)[a]		
Center, ground	5	6
Center, tree	5	6
Downwind, 100 m	5	7
Downwind, 200 m	5	7
Downwind, 300 m	5	7
Spiny mouse		
Center	1	1
Gerbil		
Center	1	-
Chameleon		
Center	-	1
Crickets		
Center	-	2

[a]All except two quelea 300 m downwind died.

Table 3. Description of spray sites, spray parameters, and estimated kill during control operations of two quelea nesting colonies on Kulalu Ranch, Kenya, 1985.

	Colony	
	Crocodile	Ranch
Spray site		
Size (ha)	10	40[a]
Mean no. active nests/ha	2,380 ± 428 (± 1SD)	2,624 ± 384 (± 1SD)
Total no. active nests/colony	23,800	104,960
% nests occupied	91	90
Installation date	21, 22 Mar	26,27 Mar; 3, 4 Apr[a]
Composition on spray night	24- to 28-day-old young and a few roosting adults	20- to 22-day-old young and roosting adults, eggs in small section of colony
Total no. birds		
Nesting adults, nestlings, fledglings	50,000	500,000-750,000
Roosting adults and juveniles	5,000	1,000,000-1,500,000
Spray parameters		
Date	25 Apr	4 May
Time	1820-1830	1835-1840
Vol (L) Queletox & fenthion (L)[b]	40, 24	100, 60
No. passes above colonies	3-1/2	7
Ambient temperature (°C)	24	24
Wind speed at 2-m height (km/h)	14.5	3.6
Flight height (m)[c]	30-45	10
Flight speed (km/h)	167	167
Atomize (r/min)	5,400	5,400
Flow rate (L/min/MICRONAIR AU 4000 atomizer)	21.5	21.5
Droplet size (μ, vmd)	80	80
Estimated kill		
% adults	<5	>75
% nestlings, juveniles, fledglings	≥50	≥75

[a]Two contiguous colonies with different installation dates: 10 ha (26, 27 Mar), 30 ha (3, 4 Apr).
[b]Queletox[R] = 60% fenthion.
[c]Height above tallest canopy.

Table 4. Mean number (± 1SD)/cm^2) of Queletox(R) droplets counted on droplet cards along three transects placed on the ground and in a 4-m tree in the center of Ranch colony and on the ground at 100-m intervals downwind of the colony.

Card location	Transect 1	Transect 2	Transect 3	Average
Colony (tree)	44.0 ± 15.7	34.6 ± 15.8	61.4 ± 20.1	46.7 ± 19.7
Colony (ground)	25.0 ± 5.4	15.4 ± 5.1	18.2 ± 5.1	19.5 ± 6.6
100 m downwind	13.2 ± 4.5	12.9 ± 8.2	37.0 ± 13.1	20.7 ± 14.6
200 m downwind	11.4 ± 6.7	6.2 ± 4.0	6.4 ± 2.6	8.0 ± 5.0
300 m downwind	4.0 ± 2.6	6.8 ± 2.6	8.8 ± 4.4	6.5 ± 3.7
400 m downwind	4.2 ± 2.4	5.8 ± 3.3	6.2 ± 4.2	5.4 ± 3.3
500 m downwind	2.6 ± 1.5	2.2 ± 1.1	2.2 ± 1.3	2.4 ± 1.2
600 m downwind	2.6 ± 1.5	1.0 ± 1.2	0.6 ± 0.5	1.4 ± 1.4
700 m downwind	0.6 ± 0.5	2.2 ± 1.3	2.0 ± 1.8	1.6 ± 1.5

Table 5. Number of fenthion droplets/cm^3 of air (as extrapolated from droplet counts on oil-sensitive filter paper) with height above ground and downwind distance from center of colonies.

Colony	Ht. (m)	Distance downwind (m)							
		25	50	75	100	125	150	175	200
CROCODILE									
Transect I									
	2.5	44	99	190	139	147	157	126	110
	1.0	62	114	78	106	94	146	89	74
	0.3	8	6	22	45	51	37	33	28
Transect II									
	2.5	25	87	140	134	180	142	108	88
	1.0	15	54	100	86	111	114	76	83
	0.3	0	12	11	36	41	23	18	13
RANCH									
Transect I									
	2.5	7	34	118	108	124	83	56	62
	1.0	64	24	38	75	69	65	74	78
	0.3	14	3	17	38	48	18	28	19
Transect II									
	2.5	34	71	89	126	150	92	68	77
	1.0	19	54	21	50	89	74	56	48
	0.3	13	0	11	28	37	20	7	12

Table 6. Fenthion residues (μg ± 1SD) on young, flightless quelea debilitated by spraying with fenthion.[a]

Days postspray	Colony	
	Crocodile	Ranch
1	44.0 ± 28.7	83.7 ± 23.3
2	6.5 ± 3.0	19.7 ± 6.9
3	8.6 ± 3.3	10.9 ± 2.7
4	--	12.2 ± 5.7

[a]Birds collected alive under nest trees. N = 6 for all collections except Crocodile Colony, Day 1, where n = 15.

Table 7. Fenthion residues (µg) on samples of dead insects and spiders collected in treated colonies.[a]

Group	Colonies		
	Crocodile	Ranch	
	Residues	Residues	No. indiv./sample
Araneida			
Arachnida	-[b]	0.48	3
Coleoptera			
Elateridae	-	-	1
Buchidae	-	-	1
Chrysomelidae	-	-	2
Carabidae	-	23, 1.4, 0.32	5,4
Scarabaeidae	-	0.41, 0.39	5,7
Melolonthinae	-	0.91, 1.5	5,12
Rhinocerus beetle	1.3	-	
Unidentified	1.9, 0.73, 0.39	2.9	1
Dytiscidae		-	2
Tenebrionidae		-	3
Diptera			
Tupulidae (larvae)	-	0.18	2
Unidentified	1.3	-	1
Homoptera			
Unidentified	0.41	-	
Hymenoptera			
Formicidae	ND[c]	0.5	17
Unidentified	ND[c], 0.56	-	1
Orthoptera			
Acridiidae	-	5.4	9
Gryllidae	5.3, 3.7	5.8	7
Gryllidae and Tettigoniidae	-	7.2	1
Mantidae	0.89	11	1

[a]Collected 1.5 day postspray in Crocodile Colony, and 2 and 3 days postspray in Ranch Colony.
[b]Dash (-) indicates individuals of these families were not found.
[c]No residues detected a a concentration >0.16 µg/sample.

Table 8. Fenthion residues (μg) on samples of grass bunches from treated colonies.[a]

Period	Colony	
	Crocodile	Ranch
Prespray	0.28[b]	0.0
Postspray		
Day 1	38, 17	28
Day 2	-[c]	6.9
Day 3	1.9	-
Day 4	-	1.1

[a]Weights of sample bunch varied from 10.5 to 17.0 g.
[b]Reason for apparent contamination of these grasses is not known.
[c]Dash (-) indicates samples were not collected.

Table 9. Cumulative total of quelea dying after exposure in cages to fenthion spray in Crocodile Colony and 100, 200, and 300 m downwind of the colony (5 birds/cage).[a]

Date, time	Center area				Distance (m) downwind					
	Ground		Tree		100		200		300	
	Debil.	Dead	Debil.	Dead	Debil.	Dead	Debil.	Dead	Debil.	Dead
Prespray (25 Apr)										
0900-1800	0	0	0	0	0	0	0	0	0	0
Spray (25 Apr)										
1820										
Postspray (26 Apr)										
0730	2	1	3	1	2	0	1	0	0	0
0830	4	1	3	2	4	0	2	0	0	0
0930	2	3	3	2	3	1	1	3	0	0
1030	1	4	2	3	3	1	0	4	0	0
1130		5		5	2	3	1	4	0	0
1230		5		5	1	4	1	4	0	0
1330		5		5	1	4	1	4	0	0
1430		5		5	1	4		5	0	0
1530		5		5	1	4		5	0	0
1630		5		5	1	4		5	0	0
1730		5		5	1	4		5	1	0
1830		5		5		5		5	2	0
1930		5		5		5		5	2	1[b]

[a]Fenthion recovered from external washing of single dead birds at several locations was: ground--17 µg/g; tree--21 µg/g; 100 m--17 µg/g; 200 m--15 µg/g.
[b]Three of five birds had died by 1930 on 27 Apr.

Table 10. Cumulative total of quelea dying after exposure in cages to fenthion spray in Ranch Colony and 100 and 200 m downwind of the colony.

Postspray		Center area		Distance downwind	
Days	Time	Ground (5)[a]	Tree (5)	100 m (6)[a]	200 m (6)
Day 1	0800	1	0	4	2
	1200	2	0	4	4
	1800	3	1	5	4
Day 2	0800	4	2	5	5
	1200	4	2	6	5
	1800	4	2	-	6
Day 3	0800	5	4	-	-
	1200	-	4	-	-
	1800	-	4	-	-
Day 4	0800	-	5[b]	-	-

[a]Birds per cage.
[b]Last bird was sacrificed for ChE analysis.

Table 11. Location of 24 radio-equipped raptors following fenthion sprays in Crocodile Colony (C) on 25 April and Ranch Colony (R) on 4 May near Tsavo East National Park, Kenya.

Raptor no.	Colony where captured	Day of capture[a]	No. days tracked	Used area with dead and dying quelea postspray	Last location found	Apparent condition when last located
Tawny eagles						
1	C	7	2	Yes	3 km SW of R	Unknown; lost contact
2	R	12	<1	Yes	In R	Debilitated when captured
3	C	4	9	Yes	25 km SE of C	Unaffected
4	C	6	8	Yes	15 km SE of C	Unaffected
5	R	8	7	Yes	Within 2 km R	Unaffected
6	R	11	4	Yes	Within 2 km R	Unaffected
7	R	15	3	Yes	>40 km NW of R	Unaffected
8	R	12	5	Yes	18 km S of R	Unaffected
9	R	-1	18	Yes	2 km W of R	Unaffected
10	R	-2	19	Yes	4 km W of R	Unaffected
11	R	-2	19	No	30 km SE of C	Unaffected
Bateleur eagles						
1	C	8	<1	No	2 km N of C	Unknown; lost contact
2	C	9	4	No	19 km NW of C	Unaffected
3	C	10	7	Yes	15 km SE of C	Unaffected
Pale chanting goshawks						
1	R	13	3	Yes	1 km W of R	Unaffected
2	R	9	6	Yes	1 km W of R	Unaffected
3	C	7	8	Yes	3 km W of C	Unaffected
4	R	13	4	Yes	3 km SW of R	Unaffected
Gabar goshawks						
1	C	2	11	Yes	10 km SW of C	Unaffected
2	C	2	13	Yes	4 km SE of C	Unaffected
Pygmy falcons						
1	C	6	9	Yes	2 km W of C	Unaffected
2	C	6	9	Yes	2 km W of C	Unaffected
Pearl-spotted owlet						
1	R	4	2	No	In R	Dead (prespray)
2	R	8	2	Yes	2 km N of R	Dead

[a]Days are numbered from the dates fenthion was applied in Crocodile Colony (Day 0, 25 April); Ranch Colony was treated on Day 9.

Table 12. Location of 8 radio-equipped mammalian predators following fenthion sprays in Crocodile Colony (C) on 25 April and Ranch Colony (R) on 4 May near Tsavo East National Park, Kenya.

Raptor no.	Colony where captured	Day of capture[a]	No. days tracked	Used area with dead and dying quelea postspray	Last location found	Apparent condition when last located
Jackals						
1	C	2	<1	No	Apparently left area after instrumentation	Unknown; lost contact
2	C	3	3	No	1 km SE of C	Unaffected
3	R	6	9	No	3 km SE of R	Unaffected
4	R	4	11	Yes	2 km SW of R	Unaffected
5	C	5	9	Yes	In C	Unaffected
6	C	-1	16	No	5 km SW of C	Unaffected
7	C	-2	17	Yes	5 km W of C	Unaffected
Genet						
1	C	2	12	No	3 km SE of C	Unaffected

[a]Days are numbered from the dates fenthion was applied in Crocodile Colony (Day 0, 25 April); Ranch Colony was treated on Day 9.

Table 13. Location of radio-equipped doves (3), Taita fiscal (1), and quelea (20) following fenthion sprays in Crocodile Colony (C) on 25 April and Ranch Colony (R) on 4 May near Tsavo East National Park, Kenya.

Animal no.	Colony where captured	Day of capture[a]	No. days tracked	Last location found	Apparent condition when last located
Laughing doves					
1	C	-2	8	6 km SW of C	Unaffected
2	C	-2	12	4 km E of C	Unaffected
Ring-necked dove					
1	C	-2	19	14 km S of C	Unaffected
Taita fiscal					
1	R	-1	<1	In R	Unknown
Quelea					
1	C	-2	2	Recovered transmitter in C	Unknown
2	C	-2	2	Recovered transmitter in C	Unknown
3	C	-2	3	About 30 km S of C	Unknown
4	C	-2	3	Vicinity of C	Unknown
5	C	-2	3	Vicinity of C	Unknown
6	C	-2	7	5 km SW of C	Unknown
7	C	-2	7	3 km S of C	Unknown
8	C	-2	8	3 km W of C	Unknown
9	C	-2	12	6 km S of C	Unknown
10	C	-2	13	3 km SW of C	Unknown
11	C	-2	13	3 km S of C	Unknown
12	R	8	<1	Lost radio contact	Unknown
13	R	8	<1	Lost radio contact	Unknown
14	R	3	1	3 km SW of R	Unknown
15	R	3	2	2 km NE of R	Unknown
16	R	3	2	4 km E of R	Unknown
17	R	3	11	Found transmitter under bush in R, 5 days postspray	Unknown
18[b]	R	3	11	In R	Dead
19[b]	R	8	7	11 km SW of R	Dead
20[b]	R	8	12	In R during spray	Dead

[a]Days are numbered from the dates fenthion was applied in Crocodile Colony (Day 0, 25 April); Ranch Colony was treated on Day 9.
[b]Only birds located postspray in area with dead and dying quelea.

Table 14. Number of debilitated or dead nontarget birds observed and/or collected in Crocodile and Ranch quelea colonies for 5 days postspray.[a]

Location, date	Man-hours searched	No. debilitated or dead birds	Species and no.
Crocodile Colony			
26 Apr	9	2	Kenya violet-backed sunbird (1) Golden-breasted bunting (1)
27 Apr	2	6	White-headed buffalo weaver (2) Fischer's starling (2) Red-billed buffalo weaver (1) Tawny-flanked prinia (1)
28 Apr	6	3	White-crowned shrike (1) Pearl-spotted owlet (1) Crombec (1)
29 Apr	10	1	White-headed buffalo weaver (1)
30 Apr	4	1	Pygmy falcon (1)
Total	31	13	
Ranch Colony[b]			
5 May	4	8	Cut-throat (1) Pearl-spotted owlet (1) Pink-breasted lark (1) Blue-naped mousebird (3) Button quail (1) Golden-breasted starling (1)
6 May	12	11	Blue-naped mousebird (1) Button quail (4) Red bishop (5) Cut-throat (1)
7 May	16	3	Tawny eagle (1) Harlequin quail (1) White-headed buffalo weaver (1)
8 May	4	6	Tawny eagle (3) Blue-naped mousebird (3)
9 May	4	3	Red bishop (1) Button quail (1) Blue-naped mousebird (1)
Total	40	31	

[a]No debilitated or dead birds were found before spraying in either colony during ≥50 man-hours of search time. Crocodile and Ranch Colonies were sprayed on 25 April and 4 May, respectively.

[b]One debilitated white-crowned shrike was collected in Ranch Colony before spraying, but no ChE inhibitor was evident in brain.

Table 15. Rodent trapping results inside and outside each quelea colony prior to spraying the colonies with fenthion.

Colony, trapping location	Date	Number	
		Trap nights	Animals caught[a]
Ranch			
Outside	22, 23 Apr	132	3
Within	24, 25 Apr	132	5
Crocodile			
Outside	28, 29 Apr	132	0
Within	30 Apr, 1 May	132	1

[a]All captured rodents were spiney mice.

Table 16. Disappearance of dead birds placed at 25-m intervals along a 625-m transect within each colony pre- and postspray. Two birds were available at each of 25 stations during the indicated time periods.

Location	Date	Time	% birds removed or eaten	Primary scavenger
Crocodile Colony				
Prespray	23-24 Apr	1800-0900	84	Jackals
Postspray	25-26 Apr	1800-0900	90	Jackals
	26 Apr	0900-1800	8	Eagles
	26-27 Apr	1800-0900	18	Jackals
Ranch Colony				
Prespray	30 Apr-1 May	1800-0900	58	Jackals, dung beetles
Postspray	4-5 May	1800-0900	24	Jackals, dung beetles
	5 May	0900-1800	6	Dung beetles, eagles
	5-6 May	1800-0900	30	Jackals, dung beetles, eagles

FIGURE CAPTIONS

Fig. 1. Location of two quelea nesting colonies on the Kulalu Ranch, Kenya, where hazards of Queletox sprays were assessed (Crocodile and Ranch), and an unsprayed third colony.

Fig. 2. Diagrammatic illustration of spray plane flight direction and all sampling transects in two quelea nesting colonies on Kulalu Ranch, Kenya, where hazards of Queletox sprays were assessed; 1985.

Fig. 3. Fenthion residues extracted from filter cards along three transects in Crocodile Colony, 12, 24, and 48 h postspray, Kenya, 1985.

Fig. 4. Fenthion residues (cumulative from three tansect lines) extracted 14 h postspray from filter cards placed on the ground in Ranch Colony, Kenya, 1985.

Fig. 5. Location of two quelea nesting colonies sprayed with Queletox and surrounding areas where dead and dying quelea were found postspray and an unsprayed third colony. Locations of radio-equipped predators and locations of non-radio-equipped predators observed eating quelea postspray also are given.

Fig. 6. Levels of ChE activity in brains of adult and young quelea collected before and after spraying the two quelea colonies with fenthion, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

Fig. 7. Levels of ChE activity in blood and brains of raptors before and after spraying two quelea colonies with fenthion, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

Fig. 8. Levels of ChE activity in brains of nontarget bird species unaffected by fenthion sprays in two quelea colonies, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

Fig. 9. Levels of ChE activity in brains of nontarget bird species affected by fenthion sprays in two quelea colonies, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

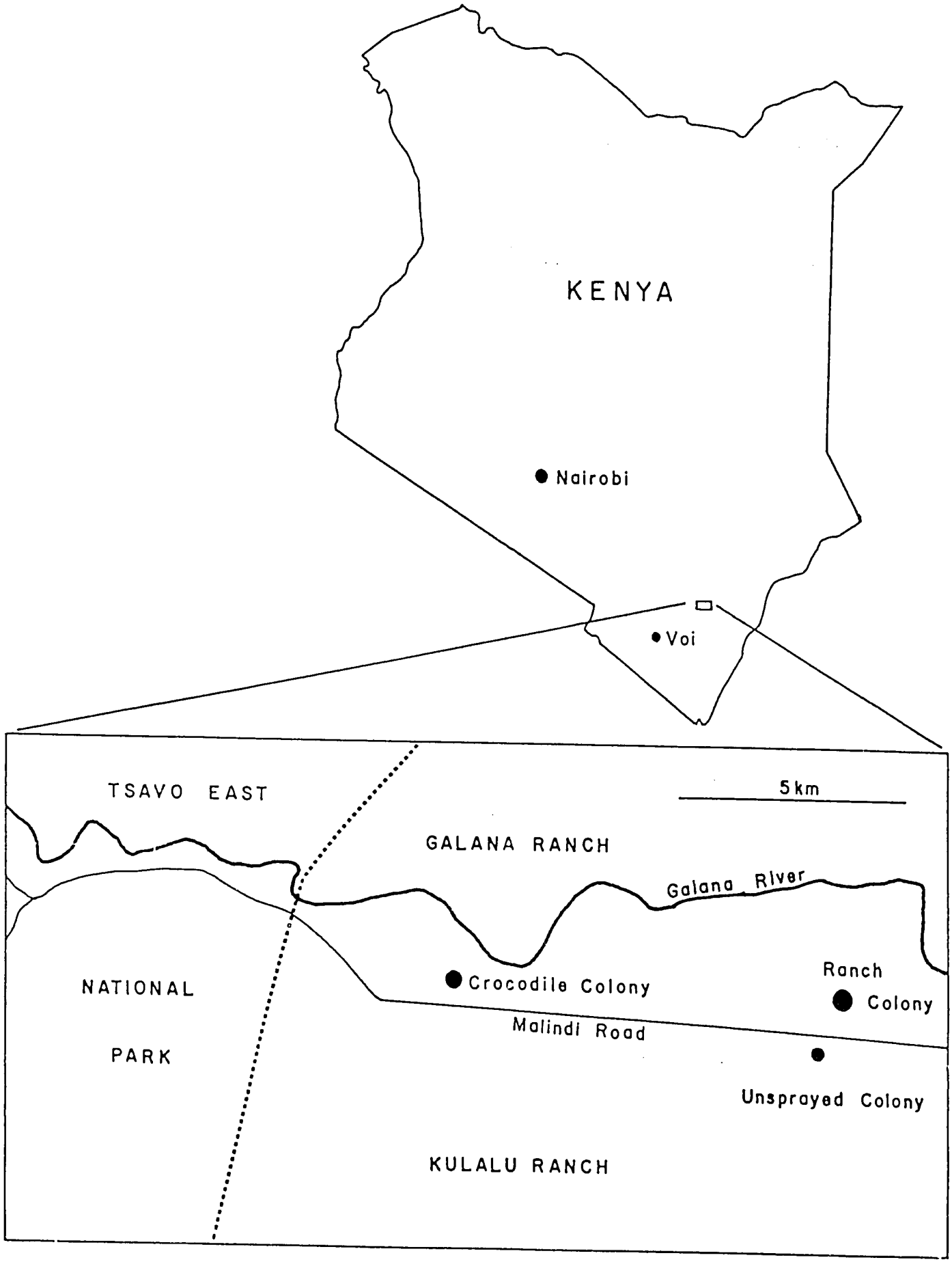

Fig. 1. Location of two quelea nesting colonies on the Kulalu Ranch, Kenya, where hazards of Queletox sprays were assessed (Crocodile and Ranch), and an unsprayed third colony.

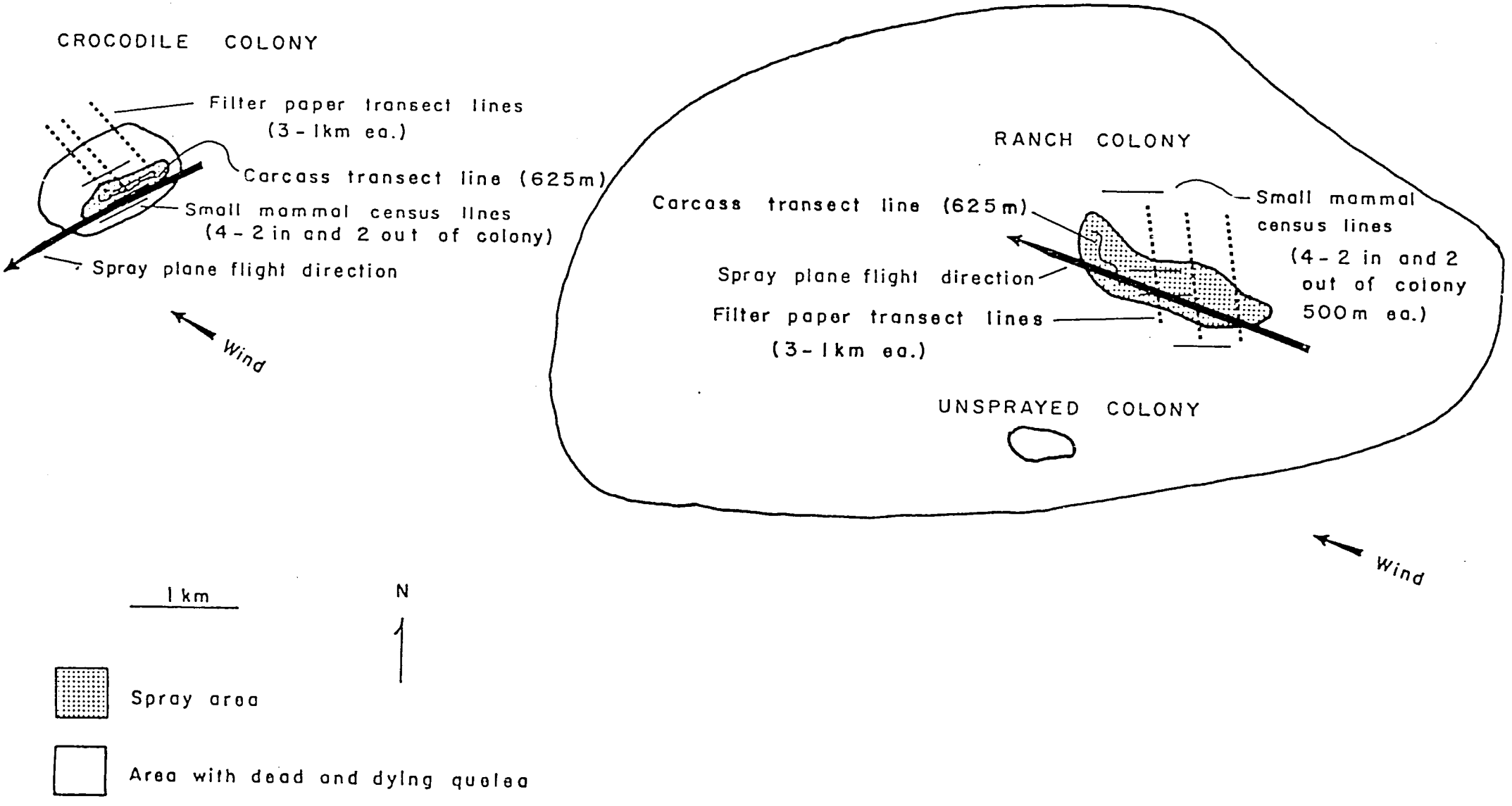

Fig. 2. Diagrammatic illustration of spray plane flight direction and all sampling transects in two quelea nesting colonies on Kulalu Ranch, Kenya, where hazards of Queletox sprays were assessed; 1985.

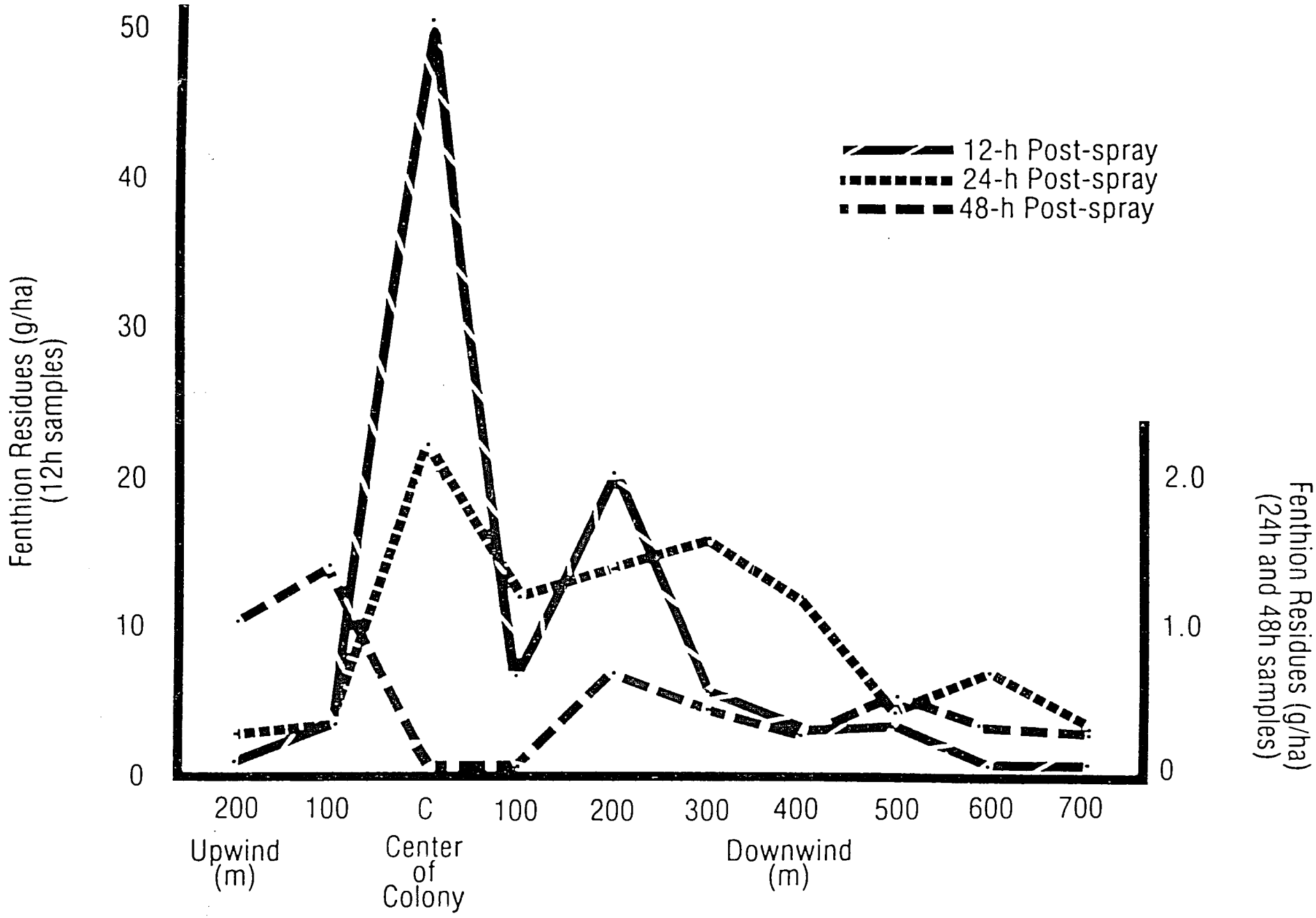

Fig. 3. Fenthion residues extracted from filter cards along three transects in Crocodile Colony, 12, 24, and 48 h postspray, Kenya, 1985.

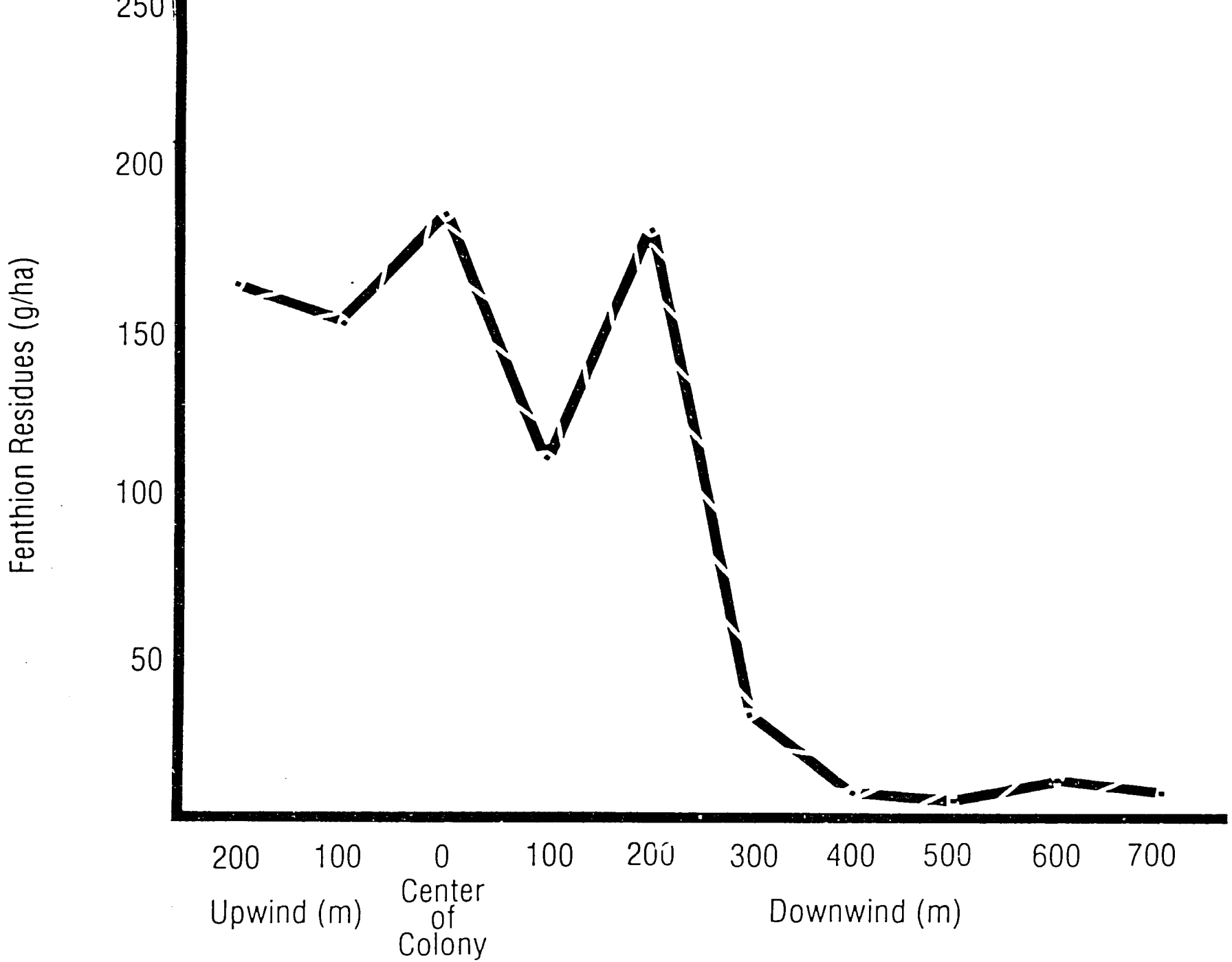

Fig. 4. Fenthion residues (cumulative from three tansect lines) extracted 14 h postspray from filter cards placed on the ground in Ranch Colony, Kenya, 1985.

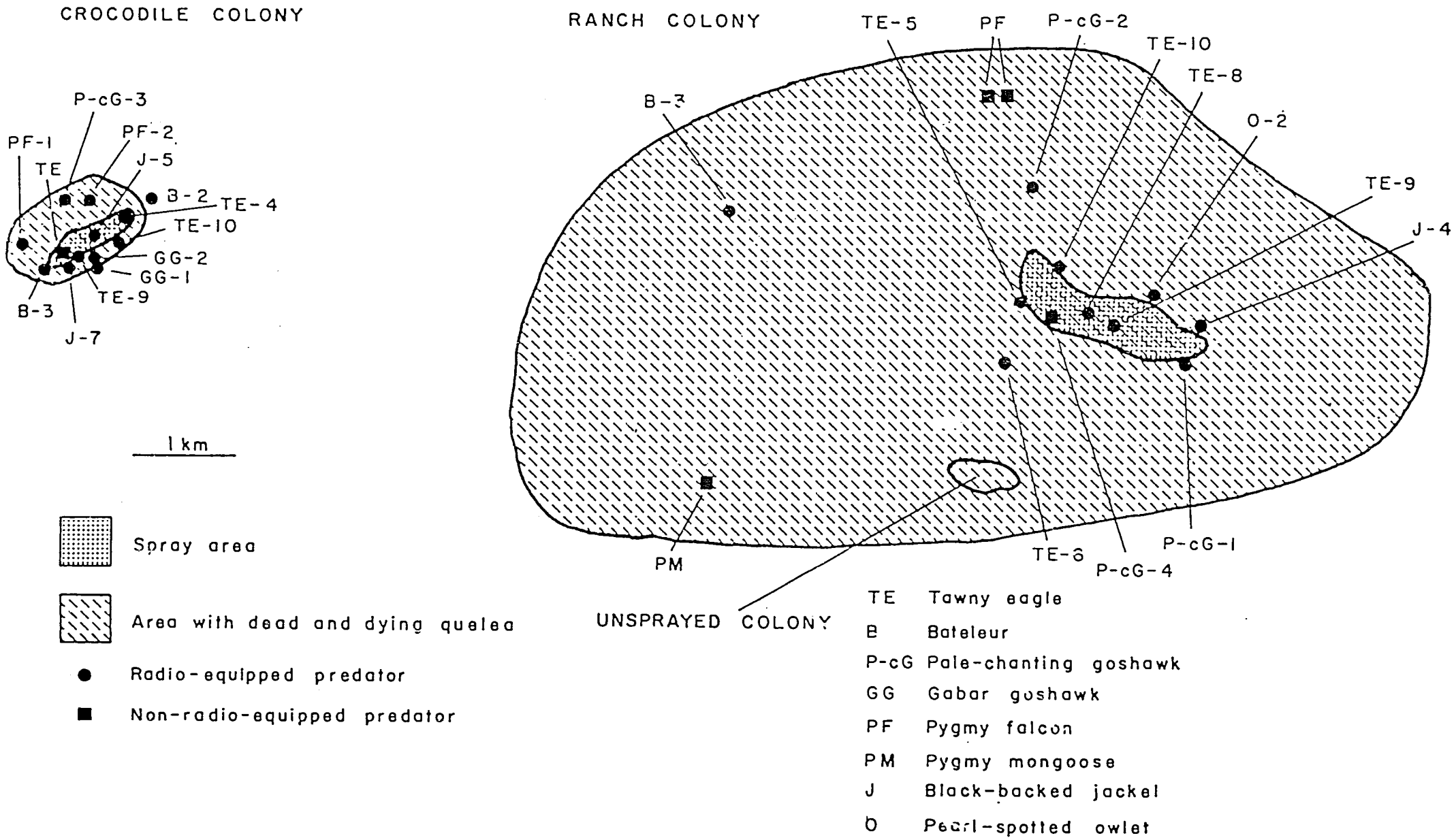

Fig. 5. Location of two quelea nesting colonies sprayed with Queletox and surrounding areas where dead and dying quelea were found postspray and an unsprayed third colony. Locations of radio-equipped predators and locations of non-radio-equipped predators observed eating quelea postspray also are given.

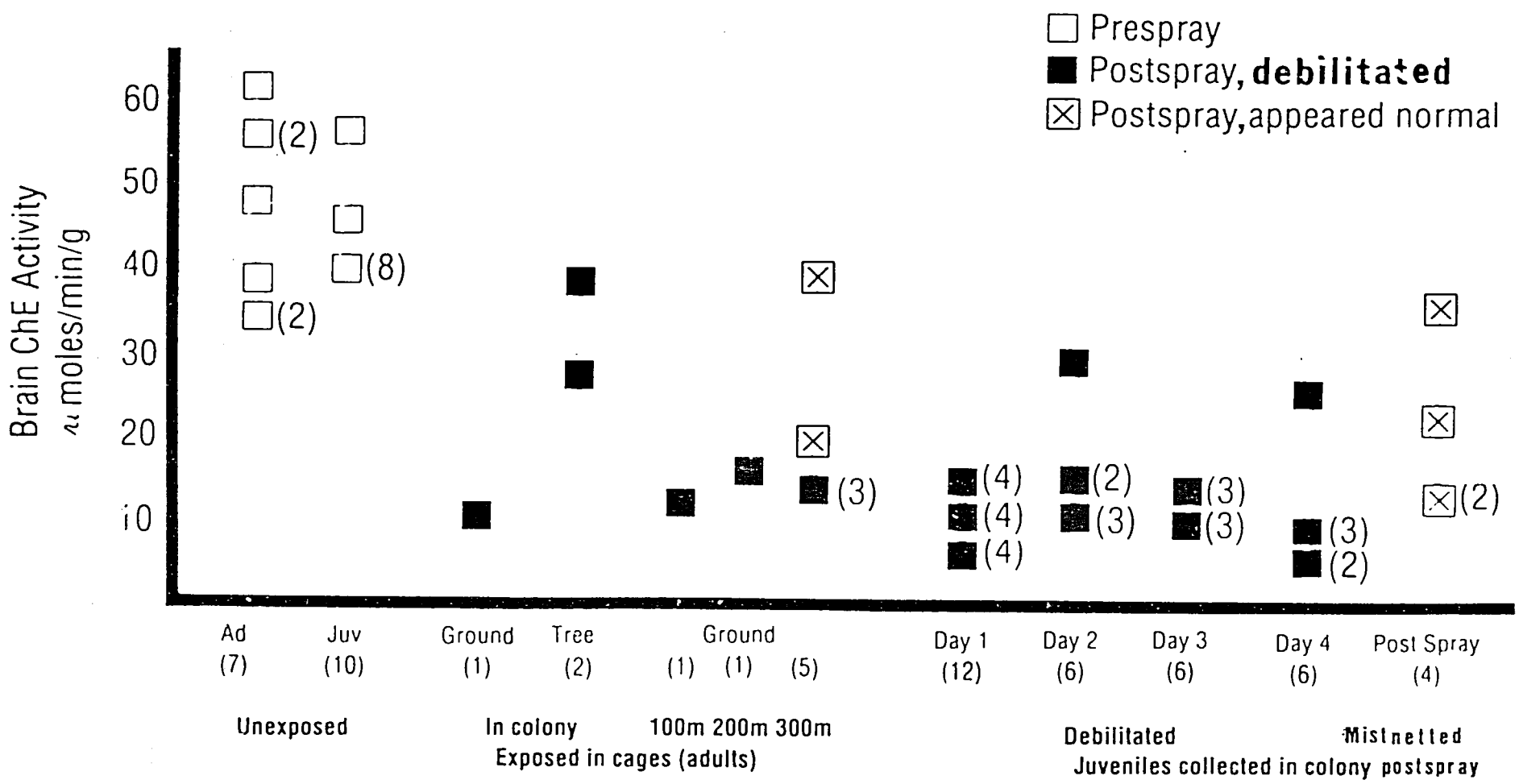

Fig. 6. Levels of ChE activity in brains of adult and young quelea collected before and after spraying the two quelea colonies with fenthion, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

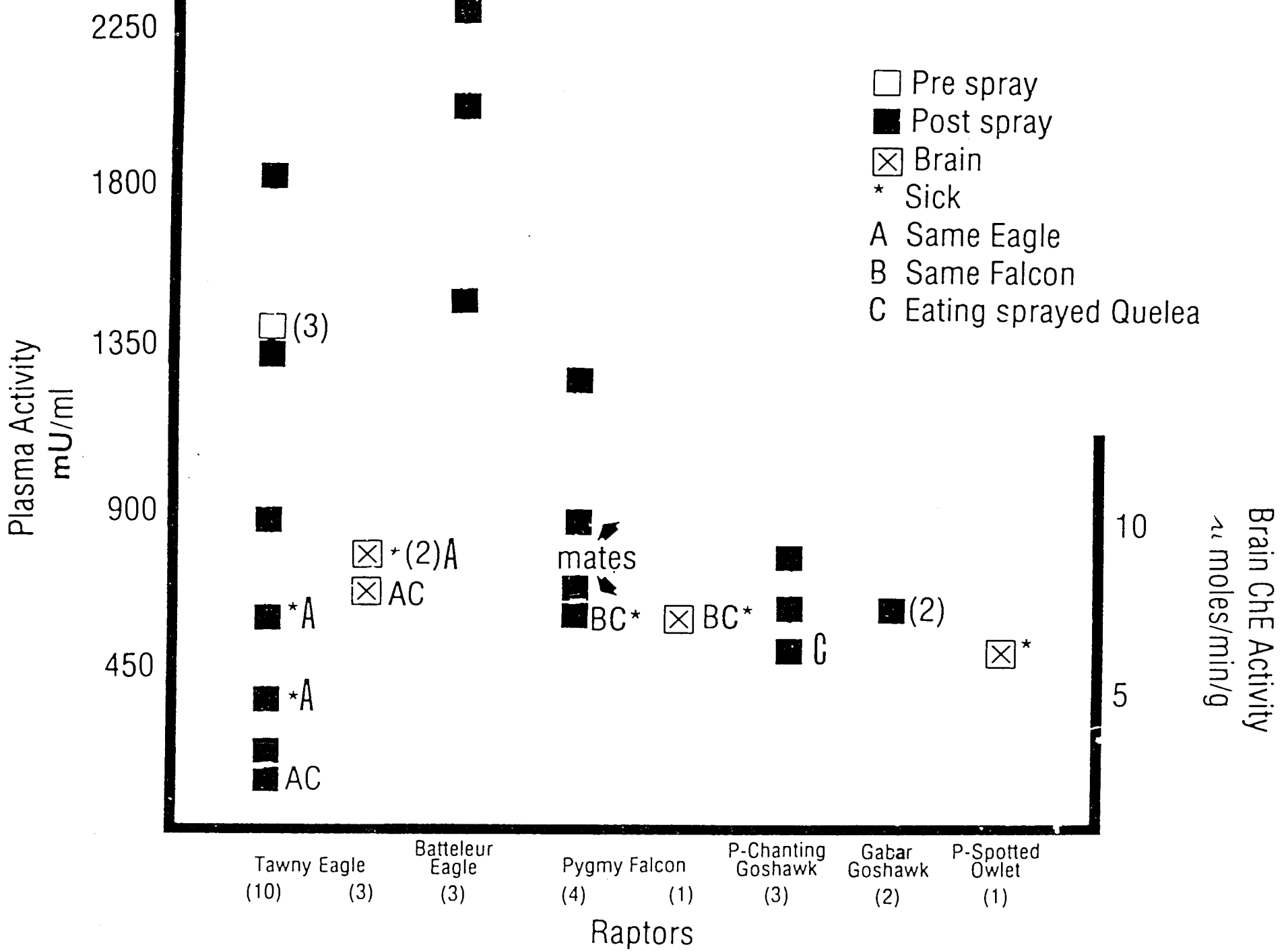

Fig. 7. Levels of ChE activity in blood and brains of raptors before and after spraying two quelea colonies with fenthion, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

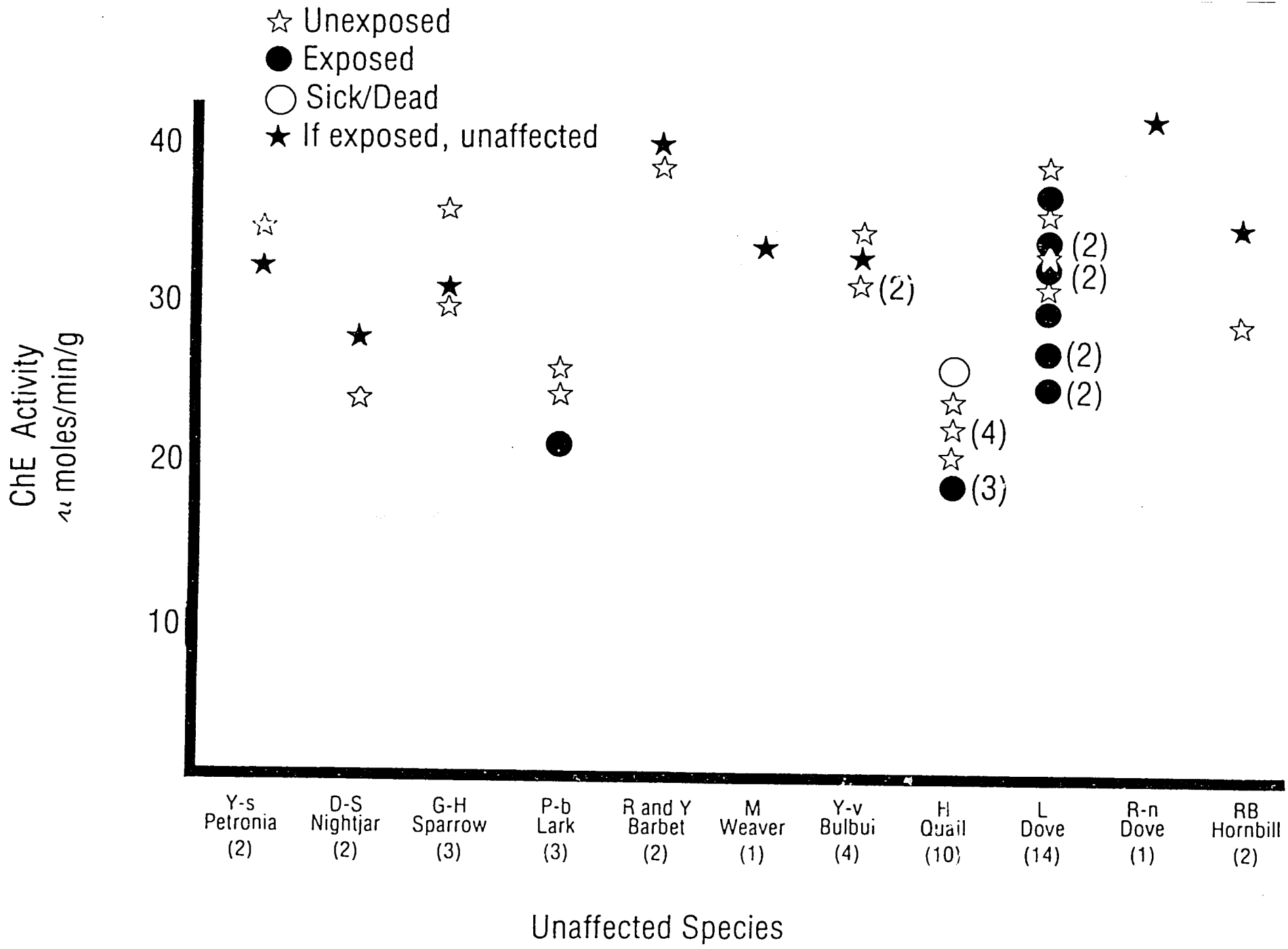

Fig. 8. Levels of ChE activity in brains of nontarget bird species unaffected by fenthion sprays in two quelea colonies, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

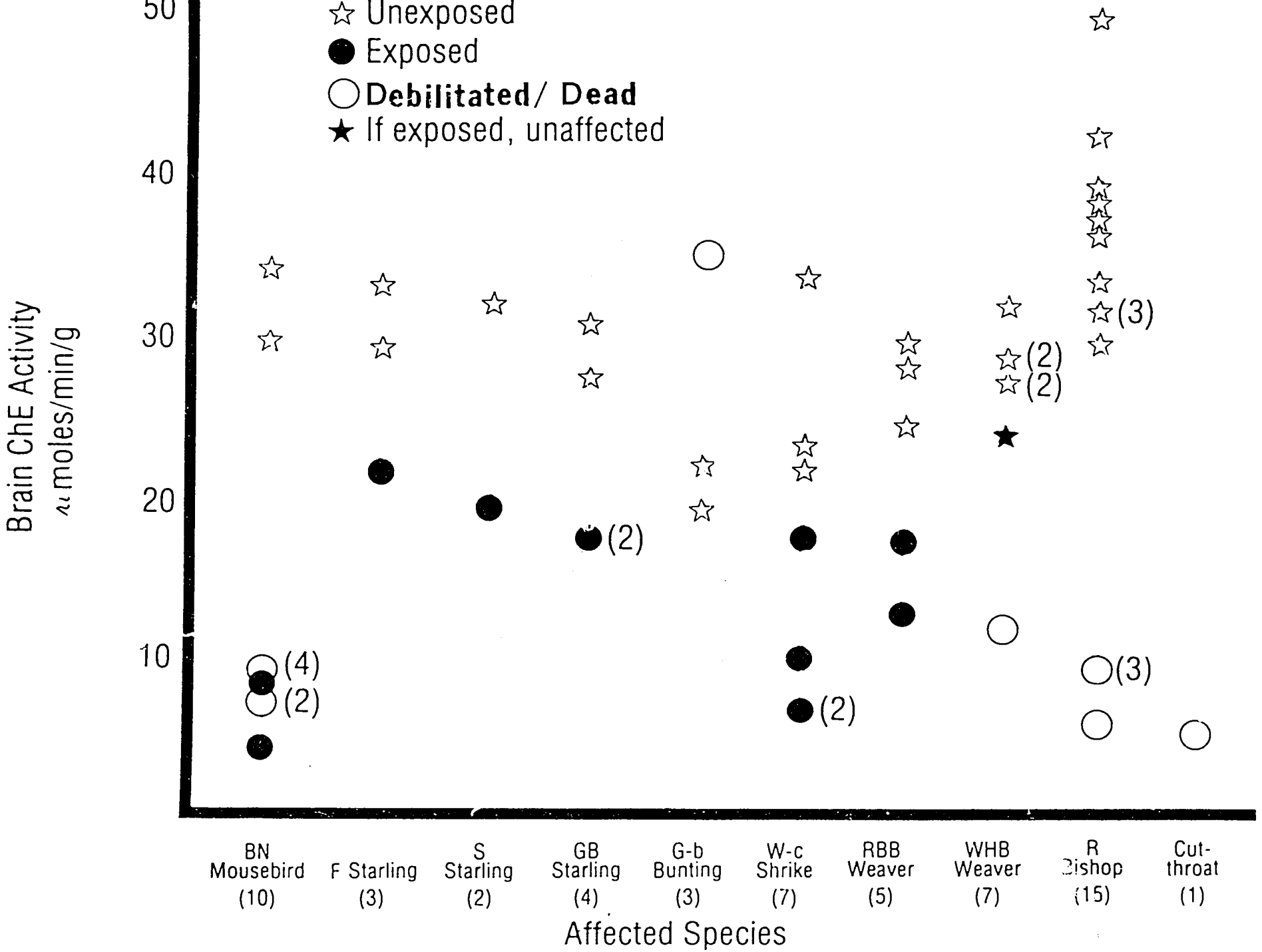

Fig. 9. Levels of ChE activity in brains of nontarget bird species affected by fenthion sprays in two quelea colonies, Kenya, 1985. Each symbol represents one bird, except where indicated by number in parentheses.

APPENDIX I. Common and scientific names of birds observed within and around two quelea colonies in Kenya prior to control operations (after Williams, 1984).

Family	Name: Common	Name: Scientific	Colony: Crocodile Outside	Colony: Crocodile Within	Colony: Ranch Outside	Colony: Ranch Within
Struthionidae						
	Ostrich	*Struthio camelus*			x	x
Ardeidae						
	Black-headed heron	*Ardea melanocephala*			x	x
	Little egret	*Egretta garzetta*			x	x
Scopidae						
	Hammerkop	*Scopus umbretta*			x	
Ciconiidae						
	Marabou stork	*Leptoptilos crumeniferus*	x			
Threskiornithidae						
	Sacred ibis	*Threskiornis aethiopicus*			x	x
Sagittariidae						
	Secretary bird	*Sagittarius serpentarius*			x	
Accipitridae						
	Nubian vulture	*Torgos tracheliotus*	x		x	
	White-headed vulture	*Trigonoceps occipitalis*	x	x	x	x
	Black-shouldered kite	*Elanus caeruleus*			x	x
	Tawny eagle	*Aquila rapax*	x	x	x	x
	Verreaux's eagle	*Aquila verreauxii*	x	x	x	
	African hawk eagle	*Hieraaetus spilogaster*	x	x	x	x
	Martial eagle	*Polemaetus bellicosus*			x	x
	Long-crested eagle	*Lophaetus occipitalis*			x	x
	Bateleur	*Terathopius ecaudatus*	x	x	x	x
	African fish eagle	*Cuncuma vocifer*	x			
	Black-chested harrier eagle	*Circaetus pectoralis*	x		x	
	Gabar goshawk	*Melierax gabar*	x	x	x	x
	Pale chanting goshawk	*Melierax poliopterus*	x		x	
Falconidae						
	Sooty falcon	*Falco concolor*			x	
	Pygmy falcon	*Poliohierax semitorquatus*	x	x	x	x

Phasianidae					
Yellow-necked spurfowl	Francolinus leucoscepus	x	x		
Vulturine guinea-fowl	Acryllium vulturinum			x	
Harlequin quail	Coturnix delegorguei	x	x	x	x
Turnicidae					
Button quail	Turnix sylvatica	x		x	x
Otididae					
Black-bellied bustard	Eupodotis melanogaster	x	x	x	x
Buff-crested bustard	Eupodotis ruficrista	x	x	x	x
Burhinidae					
Spotted stone curlew	Burhinus capensis	x		x	
Charadriidae					
Blackhead plover	Vanellus tectus	x		x	
Pteroclididae					
Black-faced sandgrouse	Pterocles decoratus	x	x	x	x
Columbidae					
Pink-breasted dove	Streptopelia lugens				
Red-eyed dove	Streptopelia semitorquata		x		
Ring-necked dove	Streptopelia capicola	x	x	x	x
Laughing dove	Streptopelia senegalensis	x	x	x	x
Mourning dove	Streptopelia decipiens	x	x		
Namaqua dove	Oena capensis	x	x	x	x
Emerald-spotted wood dove	Turtur chalcospilos			x	
Psittacidae					
Orange-bellied parrot	Poicephalus rufiventris	x			
Musophagidae					
White-bellied go-away-bird	Corythaixoides leucogaster			x	
Cuculidae					
White-browed coucal	Centropus superciliosus	x	x	x	
Coraciidae					
Lilac-breasted roller	Coracias caudata			x	
Alcedinidae					
Woodland kingfisher	Halcyon senegalensis			x	
Meropidae					
White-throated bee-eater	Merops albicollis	x			
European bee-eater	Merops apiaster			x	x
Bucerotidae					
Red-billed hornbill	Tockus erythrorhynchus	x	x	x	x
Von Der Decken's hornbill	Tockus deckeni	x		x	

Upupidae					
African hoopoe	Upupa epops	x		x	
Phoeniculidae					
Green wood hoopoe	Phoeniculus purpureus			x	
Abyssinian scimitarbill	Phoeniculus minor	x			
Strigidae					
Pearl-spotted owlet	Glaucidium perlatum	x		x	x
Verreaux's eagle owl	Bubo lacteus			x	
Caprimulgidae					
Donaldson-Smith's nightjar	Caprimulgus donaldsoni	x	x	x	x
Coliidae					
Blue-naped mousebird	Colius macrourus	x	x	x	x
Capitonidae					
D'Arnaud's barbet	Trachyphonus darnaudii	x		x	
Picidae					
Nubian woodpecker	Campethera nubica	x			
Apodidae					
Little swift	Apus affinis	x	x		
Alaudidae					
Redwinged bush lark	Mirafra hypermetra	x		x	x
Pink-breasted lark	Mirafra poecilosterna	x	x	x	x
Pycnonotidae					
Yellow-vented bulbul	Pycnonotus barbatus	x		x	
Muscicapidae					
Chin-spotted flycatcher	Batis molitor	x		x	
Turdidae					
Red-tailed chat	Cercomela familiaris	x			
Red-backed scrub robin	Erythropygia leucophrys	x		x	
Sylviidae					
Crombec	Sylvietta brachyura			x	
Tawny-flanked prinia	Prinia subflava	x	x	x	
Motacilladae					
Golden pipit	Tmetothylacus tenellus	x			
Hirundinidae					
European swallow	Hirundo rustica	x	x	x	x
Dicruridae					
Drongo	Dicrurus adsimilis	x		x	
Prionopidae					
White-crowned shrike	Eurocephalus ruppelli	x		x	x

Laniidae					
Northern brubru	Nilaus afer	x			
Fiscal shrike	Lanius collaris	x	x	x	x
Taita fiscal	Lanius dorsalis	x	x	x	x
Long-tailed fiscal	Lanius cabanisi		x		
Rosy-patched shrike	Rhodophoneus cruentus	x			
Sturnidae					
Golden-breasted starling	Cosmopsarus regius	x	x	x	x
Superb starling	Spreo superbus			x	x
Red-billed oxpecker	Buphagus erythorhynchus	x		x	x
Fischer's starling	Spreo fischeri	x	x	x	
Nectariniidae					
Hunter's sunbird	Nectarinia hunteri	x		x	
Kenya violet-backed sunbird	Anthreptes orientalis	x	x		
Emberizidae					
Golden-breasted bunting	Emberiza flaviventris	x	x		
Estrildidae					
Cut-throat	Amadina fasciata			x	
Green-winged pytilia	Pytilia melba	x	x	x	
Red-checked cordon bleu	Uraeginthus bengalus	x			
Grey-headed silverbill	Odontospiza caniceps	x			
Ploceidae					
Red-billed buffalo weaver	Bulbalornis niger	x	x	x	x
White-headed buffalo weaver	Dinemellia dinemelli	x	x	x	x
Grey-headed sparrow	Passer griseus	x		x	x
Masked weaver	Ploceus intermedius			x	
Chestnut weaver	Ploceus rubiginosus			x	x
Red-billed quelea	Quelea quelea	x	x	x	x
Red bishop	Euplectes orix	x	x	x	x
Pin-tailed whydah	Vidua macroura			x	
Yellow-spotted petronia	Petronia xanthosterna	x	x		

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APPENDIX II. Mammal species captured, observed, heard or for which signs were found in or around Crocodile and Ranch Colonies, Kenya (after Dorst and Dandelot, 1980).

Family	Names	
	Common	Scientific
Cricidae	Black-tailed gerbil	*Tatera nigricandata*
Leporidae	Hare	*Lepus* sp.
Sciuridae	Striped ground squirrel	*Xerus erythropus*
Muridae	Spiney mouse	*Acomys cahirinus*
Hystricidae	Crested porcupine	*Hystrix* sp.
Corcopithecidae	Yellow baboon	*Papio cyanocephalus*
Canidae	Bat-eared fox	*Otocyon megalotis*
	Black-backed jackal	*Canis mesomelas*
Viverridae	Common genet	*Genetta genetta*
	African civet	*Viverra civetta*
	White-tailed mongoose	*Ichneumia albicauda*
	Dwarf mongoose	*Helogale parvula*
Hyaenidae	Spotted hyena	*Crocuta crocuta*
Felidae	Caracal	*Felis caracal*
	Wild cat	*Felis libyca*
	Serval	*Felis serval*
	Leopard	*Panthera pardus*
	Lion	*Panthera leo*
Equidae	Grant's zebra	*Equus burchelli*
Suidae	Warthog	*Phacochoerus aethiopicus*
Giraffidae	Giraffe	*Giraffa camelopardalis*
Bovidae	Lesser kudu	*Tragelophus imberbis*
	Common waterbuck	*Kobus ellipsiprymnus*
	Dik-dik	*Madoqua saltiana*
	Gerenuk	*Litocranius walleri*
	Grant's gazelle	*Gazella granti*
	African buffalo	*Syncerus caffer*
Magadermatidae	African false vampire bat	*Cardioderma cor*
Mustelidae	Ratel	*Mellivora capensis*

APPENDIX III. Raptor capture techniques.

Technique	Species	Monofilament strength	Trap size, design, material
Bal-chatri trap baited with chickens and doves	Eagles	11.3-kg test, mixed with four strands of braided 5.4- and 9.0-kg test (which equaled 22- and 36-kg test nooses)	45 x 30-cm (12 mm mesh screen) base, 2.5-cm mesh poultry netting rounded top.
Bal-chatri trap baited with several quelea	Goshawks Pygmy falcons	5.4-kg test 2.7-kg test	45 x 45-cm base, hat design with 25 x 25 x 8-cm cage for bait animals made from 2.5-cm mesh screen. This trap, dropped from a vehicle moving 15-30 km/h, will land upright.
Chicken harness	Eagles	11.3-kg test	5 x 12 cm, 12 mm mesh, attached to the chickens' back. The chickens with harness on their backs were tethered and weighted.
Carcass hoops and cords	Eagles	11.3-kg test mixed with four strands of braided monofilament of various strengths	30-60 cm dia hoops were made from several strands of 14-gauge wire; portions of chicken or other animal carcasses were attached to the hoop. A weight was also attached to the hoop, which was then weighted to hold its place.

APPENDIX IVa. Fenthion residues from samples collected following sprays in two quelea colonies on Kulalu Ranch, Kenya during April-May 1985.

Sample no.	Sample	Wt. (g) or description	Solvent (mL)	Fenthion residues (µg)	Remarks
		CROCODILE COLONY (Solvent used: 100% methanol)			
850426- 1	Grasses	14.5	50	557	12 h postspray
- 2	Grasses	15.5	50	4.4	Prespray
- 3	Grasses	16.0	50	279	16 h postspray
- 4	Quelea (juv.) debilitated	17.5	20	49	16 h postspray[a]
- 5	Quelea (juv.) debilitated	17.0	20	18	16 h postspray[a]
- 6	Quelea (juv.) debilitated	16.0	20	66	16 h postspray[a]
- 7	Quelea (juv.) debilitated	17.0	20	26	16 h postspray[a]
- 8	Quelea (juv.) debilitated	17.0	20	21	16 h postspray[a]
- 9	Quelea (juv.) debilitated	17.5	20	38	16 h postspray[a]
-10	Quelea (juv.) debilitated	18.5	20	19	16 h postspray[a]
-11	Quelea (juv.) debilitated	10.0	20	18	16 h postspray[a]
-12	Quelea (juv.) debilitated	14.0	20	34	16 h postspray[a]
-13	Quelea (juv.) debilitated	15.5	20	40	16 h postspray[a]
-23	Filter papers, center line	200 m upwind	10	0.46	16 h postspray
-24	Filter papers, center line	100 m upwind	10	3.6	16 h postspray
-25	Filter papers, center line	100 m downwind	10	53	16 h postspray
-26	Filter papers, center line	200 m downwind	10	22	16 h postspray
-27	Filter papers, center line	300 m downwind	10	7.3	16 h postspray
-28	Filter papers, center line	400 m downwind	10	21	16 h postspray
-29	Filter papers, center line	500 m downwind	10	6.1	16 h postspray
-30	Filter papers, center line	600 m downwind	10	2.8	16 h postspray
-31	Filter papers, center line	700 m downwind	10	3.6	16 h postspray
-32	Filter papers, center line	800 m downwind	10	0.57	16 h postspray
-33	Filter papers, center line	900 m downwind	10	0.53	16 h postspray
-34	Quelea (juv.) debilitated	13.0	20	68	16 h postspray; dead when prepared.[a]
-35	Quelea (juv.) debilitated	17.5	20	78	16 h postspray; dead when prepared.[a]
-36	Quelea (juv.) debilitated	17.0	20	58	16 h postspray; dead when prepared.[a]
-38	Quelea (juv.) debilitated	19.5	20	115	16 h postspray; dead when prepared.[a]

-39	Quelea (juv.) debilitated	17.0	20	11	16 h postspray; dead when prepared.[a]
-40	Quelea (ad. male) dead 4/26	17.0	20	17	Exposed on ground in center group; to camp 1 h postspray.[a]
-41	Quelea (ad. male) dead 4/26	15.0	20	21	Exposed in tree in center group; to camp 1 h postspray.[a]
-42	Quelea (ad. female)	13.0	20	15	Exposed 200 m; left in colony overnight.[a]
-43	Quelea (ad. female)	13.0	20	17	Exposed 100 m; left in colony overnight.[a]
-44	Homoptera (dead)	(b)	5	0.41	16 h postspray
-45	Coleoptera (dead)	(b)	5	N.D.[c]	16 h postspray
-46	Ants (dead)	(b)	5	N.D.[c]	16 h postspray
-47	Coleoptera (dead)	(b)	5	1.9	16 h postspray
-48	Coleoptera (dead)	(b)	5	N.D.[c]	16 h postspray
-49	Hymenoptera (dead)	(b)	5	N.D.[c]	16 h postspray
-50	Coleoptera (dead)	(b)	5	0.73	16 h postspray
-51	Crickets (dead)	Large volume of mass	5	5.3	16 h postspray
-52	Leptoptera (dead)	Large volume of mass	5	N.D.[c]	16 h postspray
-53	Coleoptera (dead)	(b)	5	0.39	16 h postspray
-54	Walking stick (dead)	(b)	5	0.89	16 h postspray
-55	Crickets (dead)	Large volume of mass	5	3.7	16 h postspray
-56	Diptera (dead)	(b)	5	1.3	16 h postspray
-57	Hymenoptera (dead)	(b)	5	0.56	16 h postspray
-58	Grasshoppers (dead)	Large volume of mass	5	0.42	16 h postspray
-59	Filter papers, south line	Ground, center area	10	25	Picked up immediately postspray
-60	Filter papers, middle line	Ground, center area	10	220	Picked up immediately postspray
-61	Filter papers, north line	Ground, center area	10	54	Picked up immediately postspray
850427- 5	Filter papers, south line	200 m upwind	10	0.28	Picked up 24 h postspray
- 6	Filter papers, south line	100 m upwind	10	0.38	Picked up 24 h postspray
- 7	Filter papers, south line	Ground, center area	10	2.4	Picked up 24 h postspray
- 8	Filter papers, south line	Tree, center area	10	1.6	Picked up 24 h postspray
- 9	Filter papers, south line	100 m downwind	10	1.3	Picked up 24 h postspray
-10	Filter papers, south line	200 m downwind	10	1.5	Picked up 24 h postspray
-11	Filter papers, south line	300 m downwind	10	1.7	Picked up 24 h postspray
-12	Filter papers, south line	400 m downwind	10	1.3	Picked up 24 h postspray
-13	Filter papers, south line	500 m downwind	10	0.42	Picked up 24 h postspray
-14	Filter papers, south line	600 m downwind	10	0.68	Picked up 24 h postspray
-15	Filter papers, south line	700 m downwind	10	0.37	Picked up 24 h postspray
-24	Rhinoceros beetle	-	10	1.3	Found dead in colony
-33	Quelea (juv.) debilitated	15.0	20	6.6	Alive when prepared

-34	Quelea (juv.) debilitated	15.0	20	12	Alive when prepared
-35	Quelea (juv.) debilitated	15.0	20	5.4	Alive when prepared
-36	Quelea (juv.) debilitated	15.0	20	3.3	Alive when prepared
-37	Quelea (juv.) debilitated	15.0	20	4.5	Alive when prepared
-38	Quelea (juv.) debilitated	15.0	20	7.3	Alive when prepared
-39	Filter papers, north line	200 m upwind	10	1.1	Picked up 48 h postspray and extracted
-40	Filter papers, north line	100 m upwind	10	1.5	Picked up 48 h postspray and extracted
-41	Filter papers, north line	Colony, ground	10	0.40	Picked up 48 h postspray and extracted
-42	Filter papers, north line	Colony, tree	10	0.31	Picked up 48 h postspray and extracted
-43	Filter papers, north line	100 m downwind	10	0.40	Picked up 48 h postspray and extracted
-44	Filter papers, north line	200 m downwind	10	0.72	Picked up 48 h postspray and extracted
-45	Filter papers, north line	300 m downwind	10	0.51	Picked up 48 h postspray and extracted
850428- 2	Filter papers, north line	400 m downwind	10	0.26	Picked up 48 h postspray but not extracted until 70 h postspray.
- 3	Filter papers, north line	500 m downwind	10	0.56	Picked up 48 h postspray but not extracted until 70 h postspray.
- 4	Filter papers, north line	600 m downwind	10	0.35	Picked up 48 h postspray but not extracted until 70 h postspray.
- 5	Filter papers, north line	700 m downwind	10	0.31	Picked up 48 h postspray but not extracted until 70 h postspray.
- 6	Quelea (juv.) debilitated	13.5	20	8.3	Picked up alive 64 h postspray; dead when washed.
- 7	Quelea (juv.) debilitated	14.0	20	4.8	Picked up alive 64 h postspray; dead when washed.
- 8	Quelea (juv.) debilitated	11.0	20	12	Picked up alive 64 h postspray; dead when washed.
- 9	Quelea (juv.) debilitated	12.5	20	5.8	Picked up alive 64 h postspray; dead when washed.
-10	Quelea (juv.) debilitated	12.0	20	7.7	Picked up alive 64 h postspray; dead when washed.
-11	Quelea (juv.) debilitated	13.0	20	13	Picked up alive 64 h postspray; dead when washed.
-27	Millet	98.0	80	112	Exposed to spray
850429-19	Grasses	17.0	50	18	88 h postspray
850430-11	Quelea	None	20	3.2	Being eaten by peal-spotted owlet

RANCH COLONY
(Solvent used: 94.12% methanol; 5.88% acetone)

850504- 3	Filter papers, line 3	Sta. 3;ground (center)	10	117	Picked up right after spraying in p.m.
- 4	Filter papers, line 2	Sta. 3;ground (center)	10	412	Picked up right after spraying in p.m.
- 5	Filter papers, line 1	Sta. 3;ground (center)	10	86	Picked up right after spraying in p.m.
850505- 2	Quelea (juv.) debilitated	17.0	20	100	Picked up 14 h postspray
- 3	Quelea (juv.) debilitated	16.0	20	48	Picked up 14 h postspray
- 4	Quelea (juv.) debilitated	16.5	20	107	Picked up 14 h postspray
- 5	Quelea (juv.) debilitated	14.5	20	95	Picked up 14 h postspray
- 6	Quelea (juv.) debilitated	15.0	20	62	Picked up 14 h postspray
- 7	Quelea (juv.) debilitated	16.0	20	90	Picked up 14 h postspray
-14	Grasses	14.5	50	N.D.[c]	Collected prespray
-15	Grasses	10.5	50	297	Collected 14 h postspray
-25	Filter papers, lines 1,2,3	Sta. 1; 200 m upwind	20	129	Collected 14 h postspray[d]
-26	Filter papers, lines 1,2,3	Sta. 2; 100 m upwind	20	120	Collected 14 h postspray[d]
-27	Filter papers, lines 1,2,3	Sta. 3; center	20	146	Collected 14 h postspray[d]
-28	Filter papers, lines 1,2,3	Sta. 4; 100 m downwind	20	87	Collected 14 h postspray[d]
-29	Filter papers, lines 1,2,3	Sta. 5; 200 m downwind	20	142	Collected 14 h postspray[d]
-30	Filter papers, lines 1,2,3	Sta. 6; 300 m downwind	20	25	Collected 14 h postspray[d]
-31	Filter papers, lines 1,2,3	Sta. 7; 400 m downwind	20	6.8	Collected 14 h postspray[d]
-32	Filter papers, lines 1,2,3	Sta. 8; 500 m downwind	20	4.4	Collected 14 h postspray[d]
-33	Filter papers, lines 1,2,3	Sta. 9; 600 m downwind	20	8.6	Collected 14 h postspray[d]
-34	Filter papers, lines 1,2,3	Sta.10; 700 m downwind	20	6.0	Collected 14 h postspray[d]
-35	Filter papers, lines 1,2,3	Sta. 3; tree; center	20	80	Collected 14 h postspray[d]
-41A	Cut-throat	16.0	20	117	Found dead
850506-15A	Cut-throat	14.8	20	36	Found debilitated
-23A	Button quail	31.1	20	10	Found debilitated
-27	Quelea (juv.) debilitated	13.0	20	18	Picked up debilitated 40 h postspray
-28	Quelea (juv.) debilitated	11.2	20	33	Picked up 40 h postspray
-29	Quelea (juv.) debilitated	10.8	20	16	Picked up 40 h postspray
-30	Quelea (juv.) debilitated	11.9	20	16	Picked up 40 h postspray
-31	Quelea (juv.) debilitated	12.6	20	14	Picked up 40 h postspray
-32	Quelea (juv.) debilitated	12.0	20	21	Picked up 40 h postspray
-33	Grasses	15.5	50	107	Collected 48 h postspray
-39	Wing of quelea	0.5	10	0.99	Being eaten by pygmy falcon

850507-14	Quelea (juv.) debilitated	13.7	20	6.7	Picked up 64 h postspray
-15	Quelea (juv.) debilitated	13.7	20	8.7	Picked up 64 h postspray
-16	Quelea (juv.) debilitated	13.0	20	13	Picked up 64 h postspray
850507-17	Quelea (juv.) debilitated	15.0	20	14	Picked up 64 h postspray
-18	Quelea (juv.) debilitated	10.7	20	11	Picked up 64 h postspray
-19	Quelea (juv.) debilitated	11.6	20	12	Picked up 64 h postspray
-29	Grasses	10.8	50	20	Collected 72 h postspray
850508-22	Quelea (juv.) debilitated	12.0	20	19	Picked up 88 h postspray
-23	Quelea (juv.) debilitated	12.5	20	19	Picked up 88 h postspray
-24	Quelea (juv.) debilitated	11.4	20	7.4	Picked up 88 h postspray
-25	Quelea (juv.) debilitated	13.6	20	12	Picked up 88 h postspray
-26	Quelea (juv.) debilitated	12.2	20	5.8	Picked up 88 h postspray
-27	Quelea (juv.) debilitated	13.1	20	10	Picked up 88 h postspray
950506-42	Melolonthinae	(b)	5	0.91	Collected dead 5/5 and 5/6/85
-43	Melolonthinae	(b)	5	1.5	Collected dead 5/5 and 5/6/85
-44	Carabidae	(b)	5	23	Collected dead 5/5 and 5/6/85
-45	Carabidae	(b)	5	1.4	Collected dead 5/5 and 5/6/85
-46	Scarabaeidae	(b)	5	0.41	Collected dead 5/5 and 5/6/85
-47	Tupulidae	(b)	5	0.18	Collected dead 5/5 and 5/6/85
-48	Mantidae	(b)	5	11	Collected dead 5/5 and 5/6/85
-49	Carabidae	(b)	5	0.32	Collected dead 5/5 and 5/6/85
-50	Scarabaeidae	(b)	5	0.39	Collected dead 5/5 and 5/6/85
-51	Gryllidae	(b)	5	5.8	Collected dead 5/5 and 5/6/85
52	Formicidae	(b)	5	0.50	Collected dead 5/5 and 5/6/85
-53	Tettigoniidae	(b)	5	7.2	Collected dead 5/5 and 5/6/85
-54	Acridiidae	(b)	5	5.4	Collected dead 5/5 and 5/6/85
-55	Arachnidae	(b)	5	0.48	Collected dead 5/5 and 5/6/85
-56	Unidentified	(b)	5	2.9	Collected dead 5/5 and 5/6/85

[a]Brains were also analyzed.
[b]Individual sample too light to weigh.
[c]No residues detected at a concentration of >0.16 µg/sample.
[d]Composites of filter papers from all three lines by stations.

APPENDIX IVb: Cholinesterase levels (µm/g) in passerines and one jackal collected before or after fenthion sprays in two quelea colonies on Kulalu Ranch, Kenya; 1985.

Species	Sample no.	Age	Treatment	ChE µm/g	Condition[a]	Capture method	Location
Blue-naped mousebird	502- 7	Ad	Unexposed	34.0		MN[b]	Malindi Rd.
	502- 8	Juv.	Unexposed	29.6		MN	Malindi Rd.
	506-11	Juv.	Exposed	9.4	Debilitated	Hand	Ranch Colony
	508- 5	Juv.	Exposed	9.1	Debilitated	Hand	Ranch Colony
	505-40	Juv.	Exposed	8.6	Dead	Hand	Ranch Colony
	508-17	Juv.	Exposed	8.3	Debilitated	Hand	Ranch Colony
	508- 6	Juv.	Exposed	8.0	Debilitated	Hand	Ranch Colony
	509- 9	Juv.	Exposed	7.3	Debilitated	Hand	Ranch Colony
	509- 4	Juv.	Exposed	7.1		Shot	Ranch Colony
	505-38	Juv.	Exposed	4.2	Debilitated	Hand	Ranch Colony
Cut-throat	506-15	Juv.	Exposed	4.8	Debilitated	Hand	Ranch Colony
Donaldson-Smith's nightjar	428-28	Ad	Exposed[c]	27.8		MN	N. of Crocodile Colony
	503- 1	Ad	Unexposed	23.8		Hand	Malindi Rd.
Fischer's starling	509-21	?	Unexposed	32.9		Shot	6.5 km N of Ranch Colony
	509-22	?	Unexposed	28.7		Shot	6.5 km N of Ranch Colony
	429-13	Juv.	Exposed	21.6		MN	N of Crocodile Colony
Golden-breasted bunting	426-37	Ad	Exposed	19.1	Debilitated	Hand	Crocodile Colony
	502- 3	Juv.	Unexposed	32.1		MN	Malindi Rd.
	502-13	Juv.	Unexposed	34.6		MN	Malindi Rd.
Golden-breasted starling	422- 2	Ad	Unexposed	27.1		MN	Crocodile Colony
	422- 3	Ad	Unexposed	30.0		MN	Crocodile Colony
	509- 5	Ad	Exposed	16.9		Shot	Ranch Colony
	508-28	Juv.	Exposed	17.2		Shot	Ranch Colony
Grey-headed sparrow	424-11	Ad	Unexposed	35.7		MN	Crocodile Colony
	424-13	Juv.	Unexposed	29.9		MN	Crocodile Colony
	506-35	Juv.	Exposed[c]	30.3		MN	Ranch Colony

Harlequin quail	503- 9	-	-	22.5		-	-
	501-23	-	Unexposed	20.0		MN	Ranch Colony
	428-20	Ad	Unexposed	22.5		MN	Ranch Colony
	428-18	Ad	Unexposed	18.7		MN	Ranch Colony
	428-19	Ad	Unexposed	21.4		MN	Ranch Colony
	507- 5	Juv.	Exposed[c]	27.0	Debilitated	Hand	Ranch Colony
	509- 1	Juv.	Exposed[c]	24.5		MN	Ranch Colony
	505-22	Ad	Exposed[c]	23.2			Exposure cage
	505-23	Ad	Exposed[c]	18.7			Exposure cage
	505-24	Juv.	Exposed[c]	19.8			Exposure cage
Laughing dove	421-15	Ad	Unexposed	33.9		MN	Crocodile Colony
	422- 7	Ad	Unexposed	37.2		MN	Crocodile Colony
	421-14	Ad	Unexposed	30.6		MN	Crocodile Colony
	421-16	Ad	Unexposed	33.2		MN	Crocodile Colony
	426-64	Ad	Exposed[c]	35.6		MN	Crocodile Colony
	427-22	Ad	Exposed[c]	32.5		MN	Crocodile Colony
	506- 8	Juv.	Exposed[c]	28.6		MN	Ranch Colony
	507-34	Juv.	Exposed[c]	33.3		MN	Ranch Colony
	505-17	Ad	Exposed[c]	24.0			Exposure cage
	505-19	Ad	Exposed[c]	24.9			Exposure cage
	505-20	Ad	Exposed[c]	33.2			Exposure cage
	505-21	Ad	Exposed[c]	26.2			Exposure cage
	505-16	Juv.	Exposed[c]	32.8			Exposure cage
	505-18	Juv.	Exposed[c]	26.3			Exposure cage
Leaf-nosed bat	422-14	-	Unexposed	21.8		MN	Crocodile Colony
	427-26	-	Exposed	17.5		MN	Crocodile Colony
	508-20	-	Exposed	16.6		MN	Ranch Colony
Pink-breasted lark	421-18	Ad	Unexposed	23.6		MN	Crocodile Colony
	424-12	Ad	Unexposed	25.4		MN	Crocodile Colony
	507- 7	Ad	Exposed	20.8		MN	Ranch Colony
Masked weaver	507- 6	Juv.	Exposed[c]	33.0		MN	Ranch Colony
Red-billed quelea (Prespray)	421- 1	Juv.	Unexposed	40.6		MN	Crocodile Colony
	422-16	Juv.	Unexposed	40.2		MN	Crocodile Colony
	421- 4	Juv.	Unexposed	56.3		MN	Crocodile Colony
	422-15	Juv.	Unexposed	37.8		MN	Crocodile Colony

Red-billed quelea (Postspray) cont'd	421-10	Juv.	Unexposed	45.5		MN	Crocodile Colony
	421- 9	Juv.	Unexposed	40.2		MN	Crocodile Colony
	421- 6	Juv.	Unexposed	41.0		MN	Crocodile Colony
	423- 5	Juv.	Unexposed	43.3		MN	Crocodile Colony
	424- 4	Juv.	Unexposed	38.1		MN	Crocodile Colony
	424- 6	Juv.	Unexposed	39.1		MN	Crocodile Colony
	427-16	Ad	Unexposed	61.2		MN	1 km from Crocodile Colony
	423- 4	Ad	Unexposed	47.7		MN	Crocodile Colony
	422-17	Ad	Unexposed	35.1		MN	Crocodile Colony
	424-21	Ad	Unexposed	36.5		MN	Crocodile Colony
	423- 2	Ad	Unexposed	35.5		MN	Crocodile Colony
	424-19	Ad	Unexposed	56.3		MN	Crocodile Colony
	424-20	Ad	Unexposed	56.3		MN	Crocodile Colony
Red-billed quelea (Postspray)	426-40	Ad	Exposed	10.9	Debilitated		Exposure cage; center-ground; Crocodile Colony
	426-41	Ad	Exposed[c]	37.2	Dead		Exposure cage; center-tree; Crocodile Colony
	508- 1	Ad	Exposed	26.9	Debilitated		Exposure cage; center-tree; Ranch Colony
	426-43	Ad	Exposed	12.9	Dead		Exposure cage; 100 m, Crocodile Colony
	426-42	Ad	Exposed	16.1	Debilitated		Exposure cage; 200 m, Crocodile Colony
	427- 1	Ad	Exposed	14.5	Dead		Exposure cage; 300 m, Crocodile Colony
	427- 2	Ad	Exposed	13.9	Debilitated		Exposure cage; 300 m, Crocodile Colony
	427- 3	Ad	Exposed	12.9	Debilitated		Exposure cage; 300 m, Crocodile Colony
	427- 4	Ad	Exposed[c]	38.7	OK		Exposure cage; 300 m, Crocodile Colony
	508- 3	Ad	Exposed	19.0	OK		Exposure cage; 300 m, Ranch Colony
	507-20	Juv.	Exposed	21.6		MN	Ranch Colony; flying
	507-21	Juv.	Exposed[c]	35.5		MN	Ranch Colony; flying
	507-22	Juv.	Exposed	13.2		MN	Ranch Colony; flying
	507-23	Juv.	Exposed	12.7		MN	Ranch Colony; flying

Red-billed quelea (Postspray, Day 1)	426-38	Yg	Exposed	11.5	Debilitated	Hand	Crocodile Colony
	426-34	Yg	Exposed	11.9	Debilitated	Hand	Crocodile Colony
	426-36	Yg	Exposed	7.9	Debilitated	Hand	Crocodile Colony
	426-39	Yg	Exposed	12.9	Debilitated	Hand	Crocodile Colony
	426- 5	Yg	Exposed	10.6	Debilitated	Hand	Crocodile Colony
	426- 6	Yg	Exposed	14.3	Debilitated	Hand	Crocodile Colony
	426- 7	Yg	Exposed	8.2	Debilitated	Hand	Crocodile Colony
	426- 9	Yg	Exposed	13.2	Debilitated	Hand	Crocodile Colony
	426-10	Yg	Exposed	8.9	Debilitated	Hand	Crocodile Colony
	426-11	Yg	Exposed	8.0	Debilitated	Hand	Crocodile Colony
	426-12	Yg	Exposed	6.0	Debilitated	Hand	Crocodile Colony
	426-13	Yg	Exposed	6.9	Debilitated	Hand	Crocodile Colony
Red-billed quelea (Postspray, Day 2)	427-27	Yg	Exposed	14.0	Debilitated	Hand	Crocodile Colony
	427-28	Yg	Exposed	12.6	Debilitated	Hand	Crocodile Colony
	427-29	Yg	Exposed	11.1	Debilitated	Hand	Crocodile Colony
	427-30	Yg	Exposed	11.2	Debilitated	Hand	Crocodile Colony
	427-31	Yg	Exposed	14.0	Debilitated	Hand	Crocodile Colony
	427-32	Yg	Exposed	28.4	Debilitated	Hand	Crocodile Colony
Red-billed quelea (Postspray, Day 3)	428-12	Yg	Exposed	12.2	Debilitated	Hand	Crocodile Colony
	428-13	Yg	Exposed	11.6	Debilitated	Hand	Crocodile Colony
	428-14	Yg	Exposed	13.7	Debilitated	Hand	Crocodile Colony
	428-15	Yg	Exposed	13.6	Debilitated	Hand	Crocodile Colony
	428-16	Yg	Exposed	14.2	Debilitated	Hand	Crocodile Colony
	428-17	Yg	Exposed	10.0	Debilitated	Hand	Crocodile Colony
Red-billed quelea (Postspray, Day 4)	508-11	Yg	Exposed	25.5	Debilitated	Hand	Ranch Colony
	508-12	Yg	Exposed	9.4	Debilitated	Hand	Ranch Colony
	508-13	Yg	Exposed	7.2	Debilitated	Hand	Ranch Colony
	508-14	Yg	Exposed	4.8	Debilitated	Hand	Ranch Colony
	508-15	Yg	Exposed	8.0	Debilitated	Hand	Ranch Colony
	508-16	Yg	Exposed	7.6	Debilitated	Hand	Ranch Colony
Red-billed buffalo weaver	425- 1	Juv.	Unexposed	29.5		MN	Crocodile Colony
	509- 7	Juv.	Unexposed	27.8		MN	3 km E of Crocodile Colony
	509- 8	Juv.	Unexposed	24.0		MN	3 km E of Crocodile Colony
	426-62	Ad	Exposed	12.3		MN	Crocodile Colony
	501-19	Juv.	Exposed	16.9		MN	N of Crocodile Colony

Red-billed hornbill	508-30	-	Unexposed	27.8		Shot	5 km E of Crocodile Colony
	502-16	-	Exposed[c]	34.0		MN	Crocodile Colony
Red bishop	422-19	Ad	Unexposed	49.8		MN	Crocodile Colony
	501-16	Ad	Unexposed	39.1		MN	Crocodile Colony
	501-10	Ad	Unexposed	33.0		MN	Ranch Colony
	501-11	Ad	Unexposed	37.8		MN	Ranch Colony
	501-14	Juv.	Unexposed	32.5		MN	Crocodile Colony
	501-15	Juv.	Unexposed	31.6		MN	Crocodile Colony
	503- 5	Juv.	Unexposed	29.4		MN	Ranch Colony
	501-17	Juv.	Unexposed	32.6		MN	Crocodile Colony
	502-19	Juv.	Unexposed	42.1		MN	Crocodile Colony
	502-20	Juv.	Unexposed	35.8		MN	Crocodile Colony
	501- 9	Ad	Unexposed	36.4		MN	Ranch Colony
	506-18	Juv.	Exposed	5.8	Debilitated	Hand	Ranch Colony
	506-19	Juv.	Exposed	10.1	Debilitated	Hand	Ranch Colony
	506-20	Juv.	Exposed	9.4	Debilitated	Hand	Ranch Colony
	506-17	Juv.	Exposed	8.9	Debilitated	Hand	Ranch Colony
Red-necked dove	427-20	Ad	Exposed[c]	40.9		MN	Crocodile Colony
D'Arnaud's barbet	422-12	Ad	Unexposed	38.6		MN	Crocodile Colony
	507-25	Juv.	Exposed[c]	39.5		MN	Ranch Colony
Superb starling	429- 7	Ad	Exposed	18.7	Dead	MN	Crocodile Colony
	509- 6	Juv.	Unexposed	37.6		Shot	4 km S of Ranch Colony
White-crowned shrike	423- 8	-	Unexposed	23.6		MN	Crocodile Colony
	427-25	Ad	Unexposed	33.8		MN	N of Crocodile Colony
	501-25	Ad	Unexposed	21.8		Hand	Ranch Colony
	509- 2	Juv.	Exposed	6.5		Shot	Ranch Colony
	508-18	Juv.	Exposed	9.9		MN	Ranch Colony
	507-35	Juv.	Exposed	7.7		MN	Ranch Colony
	508-29	Juv.	Exposed	17.8		Shot	Ranch Colony
White-headed buffalo weaver	422- 1	Ad	Unexposed	26.7		MN	Crocodile Colony
	425- 7	Juv.	Unexposed	28.0		MN	Crocodile Colony
	426-20	Ad	Unexposed	31.4		MN	2 km E of Crocodile Colony
	502-14	Ad	Unexposed	26.3		MN	Ranch Colony
	502-15	Ad	Unexposed	28.1		MN	Ranch Colony
	427-19	Ad	Exposed	11.0	Debilitated	Hand	Crocodile Colony
	509- 3	Ad	Exposed	23.5		Shot	Ranch Colony

Yellow-spotted petronia	422-13	Ad	Unexposed	34.4	MN	Crocodile Colony
	501-24	Juv.	Exposed[c]	32.0	-	-
Yellow-vented bulbul	502- 2	Juv.	Unexposed	31.2	MN	Malindi Rd.
	502- 9	Juv.	Unexposed	30.1	MN	Malindi Rd.
	502-11	Juv.	Unexposed	33.8	MN	Malindi Rd.
	501- 2	Ad	Exposed[c]	32.6	MN	N of Crocodile Colony
Jackal	510- 1	-	Exposed	13.3	Trap	Ranch Colony

[a]Animals found dead or others that appeared debilitated are noted in this column.
[b]MN indicates mist-net.
[c]If actually exposed, ChE level apparently not affected.

LIST OF APPENDIX V

APPENDIX Va. Movements of quelea Nos. 10, 11, and 20. All movements are postspray except as indicated for No. 20.

APPENDIX Vb. Movements of quelea Nos. 8, 9, and 19. All movements are postspray except as indicated for No. 19.

APPENDIX Vc. Movements of quelea Nos. 3, 6, 7, and 18. All movements are postspray except as noted for No. 18.

APPENDIX Vd. Movements of perl-spotted owlet No. 2. The owlet was found moribund 1 day postspray.

APPENDIX Ve. Movements of tawny eagles Nos. 3, 4, 6, and 8. All movements are postspray (25 April for Crocodile Colony).

APPENDIX Vf. Movements of tawny eagle No. 5. All movements are postspray (25 April for Crocodile Colony).

APPENDIX Vg. Movements of tawny eagle No. 9. All movements are postspray (25 April for Crocodle Colony).

APPENDIX Vh. Movements of tawny eagle No. 10. All movements are postspray (25 April for Crocodile Colony) except as indicated.

APPENDIX Vi. Movements f tawny eagle No. 11. All movements are postspray (25 April for Crocodile Colony) except as indicated.

APPENDIX Vj. Movements of bateleur eagles Nos. 2 and 3. All movements are postspray (25 April for Crocodile Colony).

APPENDIX Vk. Movements of pale chanting goshawks Nos. 1 and 3. All movements are postspray (25 April for Crocodile Colony, and 4 May for Ranch Colony).

APPENDIX Vl. Movements of pale chanting goshawks Nos. 2 and 4. All movements are postspray (4 May for Ranch Colony).

APPENDIX Vm. Movements of gabar goshawks Nos. 1 and 2. All movements are postspray (25 April for Crocodile Colony).

APPENDIX Vn. Movements of pygmy flacons Nos. 1 and 2. All movements are postspray (25 April for Crocodile Colony).

APPENDIX Vo. Movements of black-backed jackals Nos. 2, 3, and 6. All movements are postspray (25 April for Crocodile Colony and 4 May for Ranch Colony) except as indicated for No. 3.

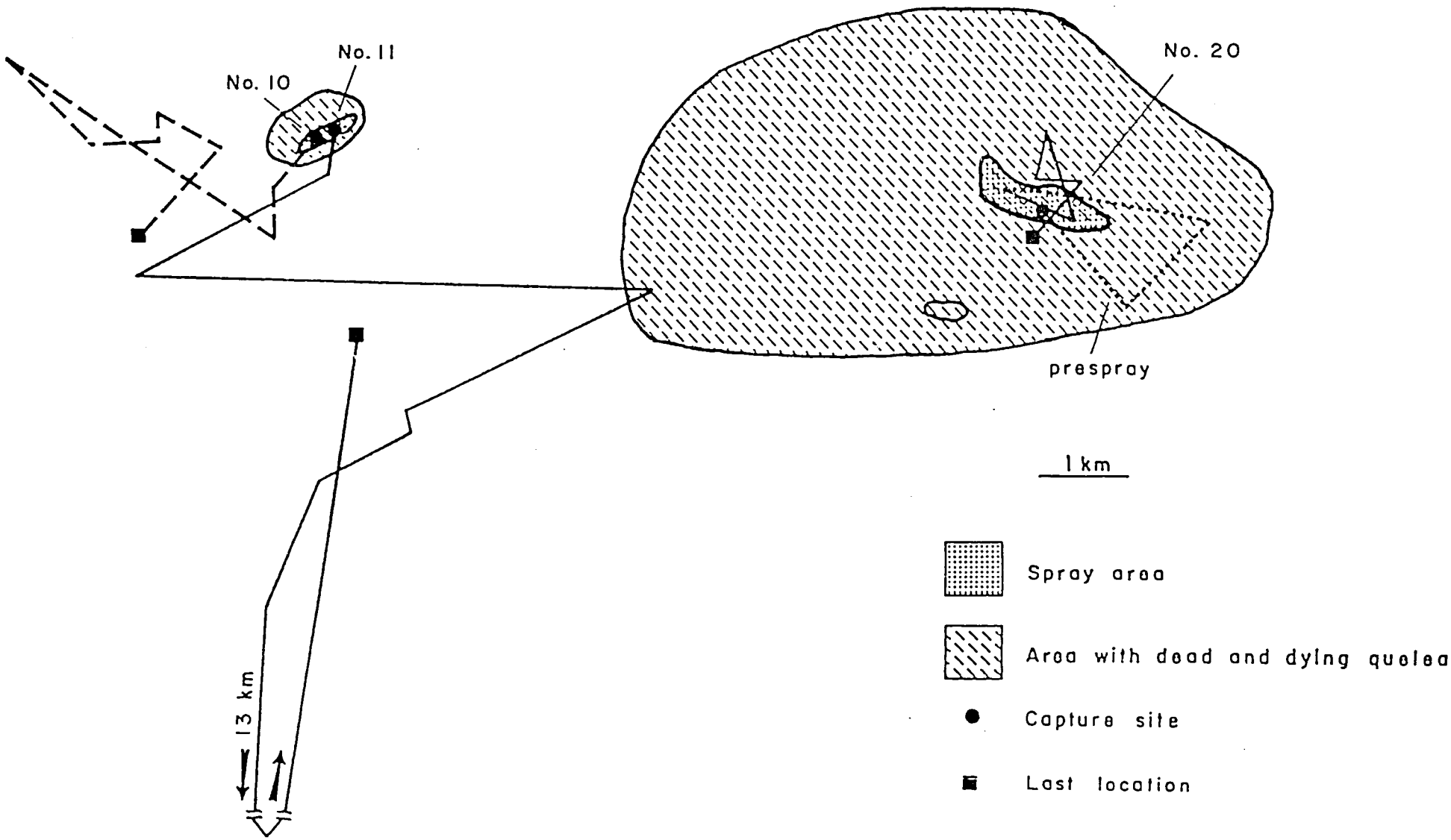
APPENDIX Vp. Movements of black-backed jackals Nos. 4, 5, and 7. All movements are postspray (25 April for Crocodile Colony and 4 May for Ranch Colony) except as indicated for No. 4.

APPENDIX Vq. Movements of common genet No. 1. All movements are postspray (25 April for Crocodile Colony).

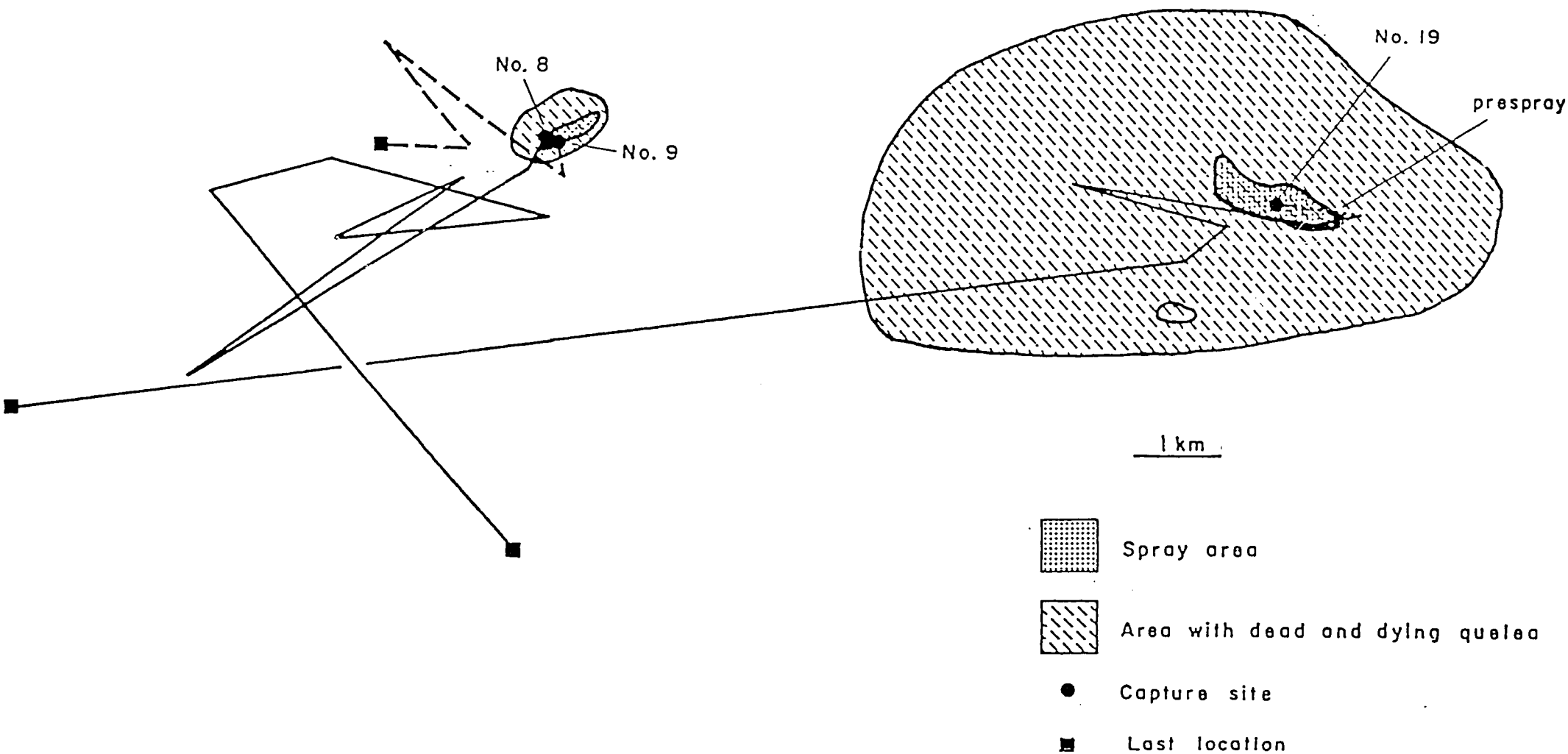
APPENDIX Vr. Movements of doves Nos. 1 and 3. All movements are postspray (25 April for Crocodile Colony) except as indicated.

APPENDIX Vs. Movements of dove No. 2. All movements are postspray (25 April for Crocodile Colony) except as indicated.

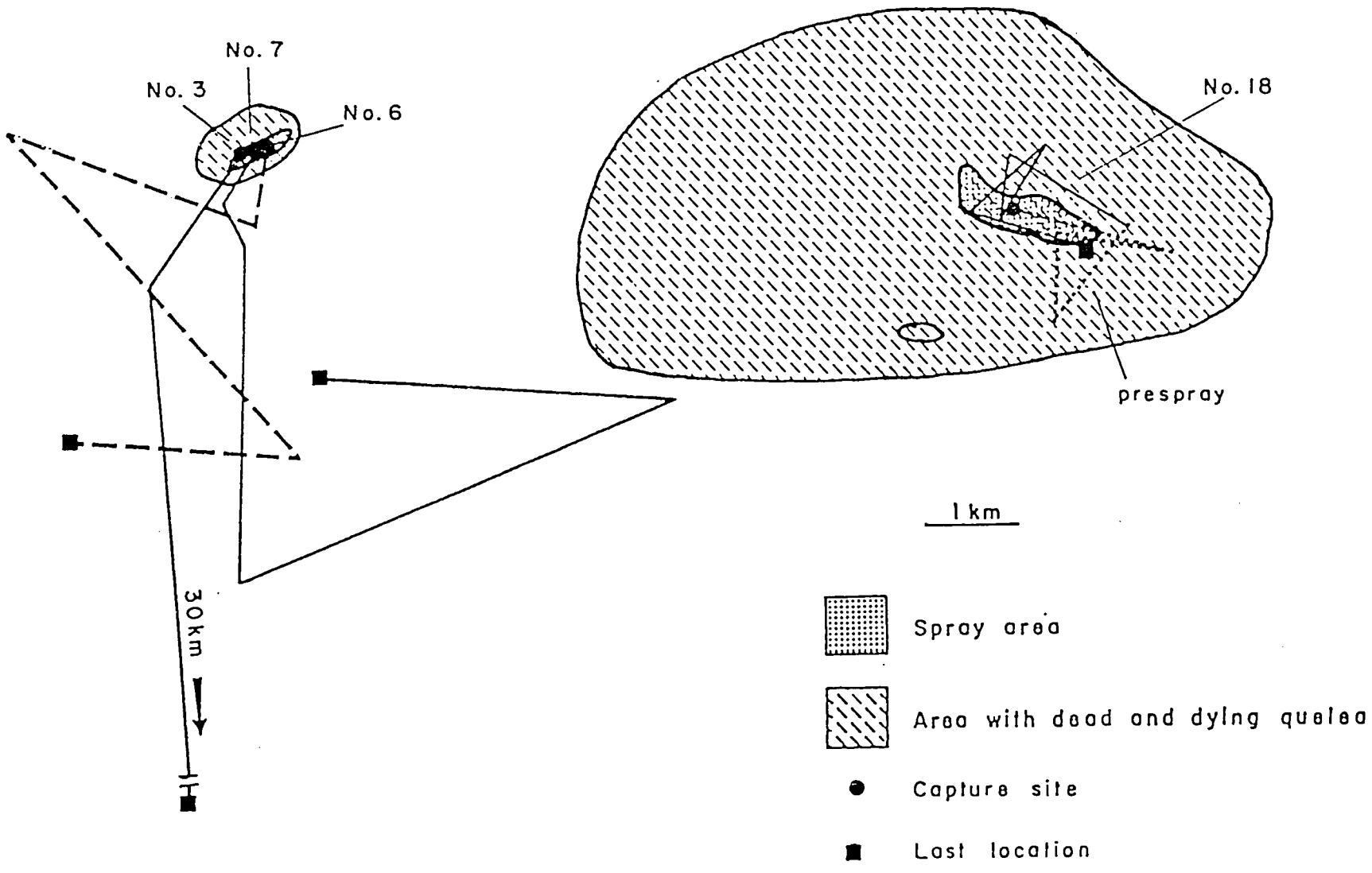
APPENDIX Va. Movements of quelea Nos. 10, 11, and 20. All movements are postspray except as indicated for No. 20.



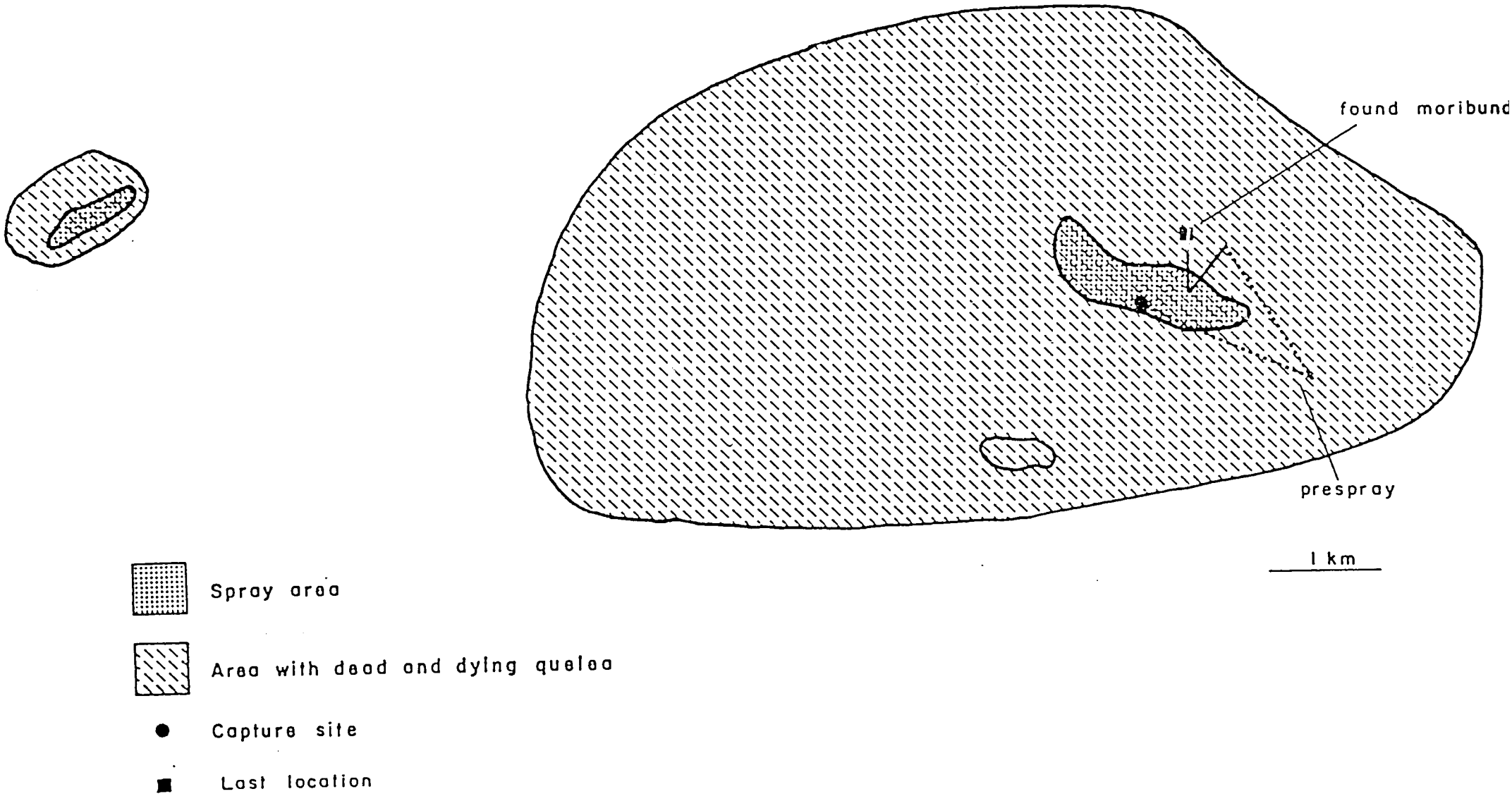
APPENDIX Vb. Movements of quelea Nos. 8, 9, and 19. All movements are postspray except as indicated for No. 19.



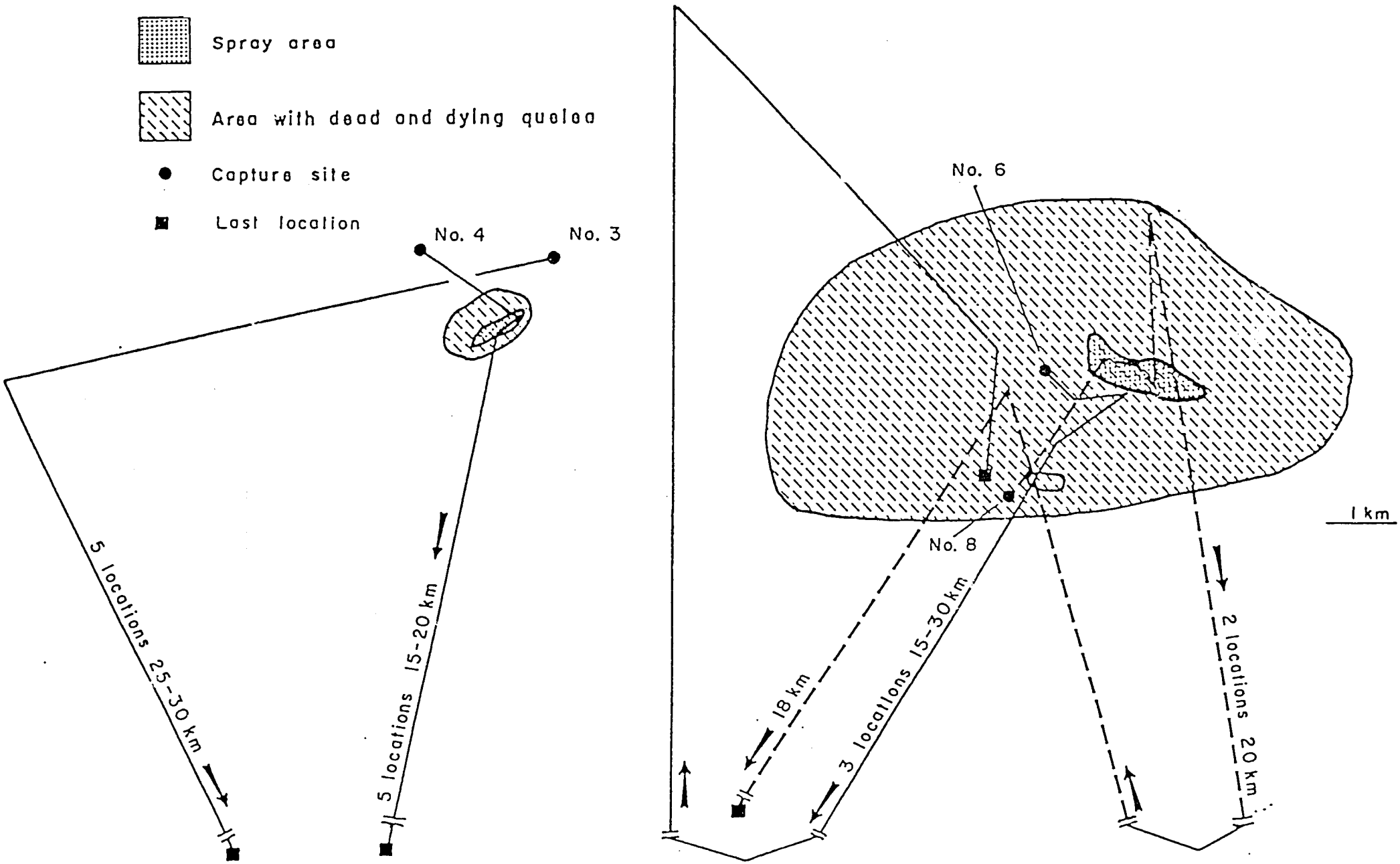
APPENDIX Vc. Movements of quelea Nos. 3, 6, 7, and 18. All movements are postspray except as noted for No. 18.



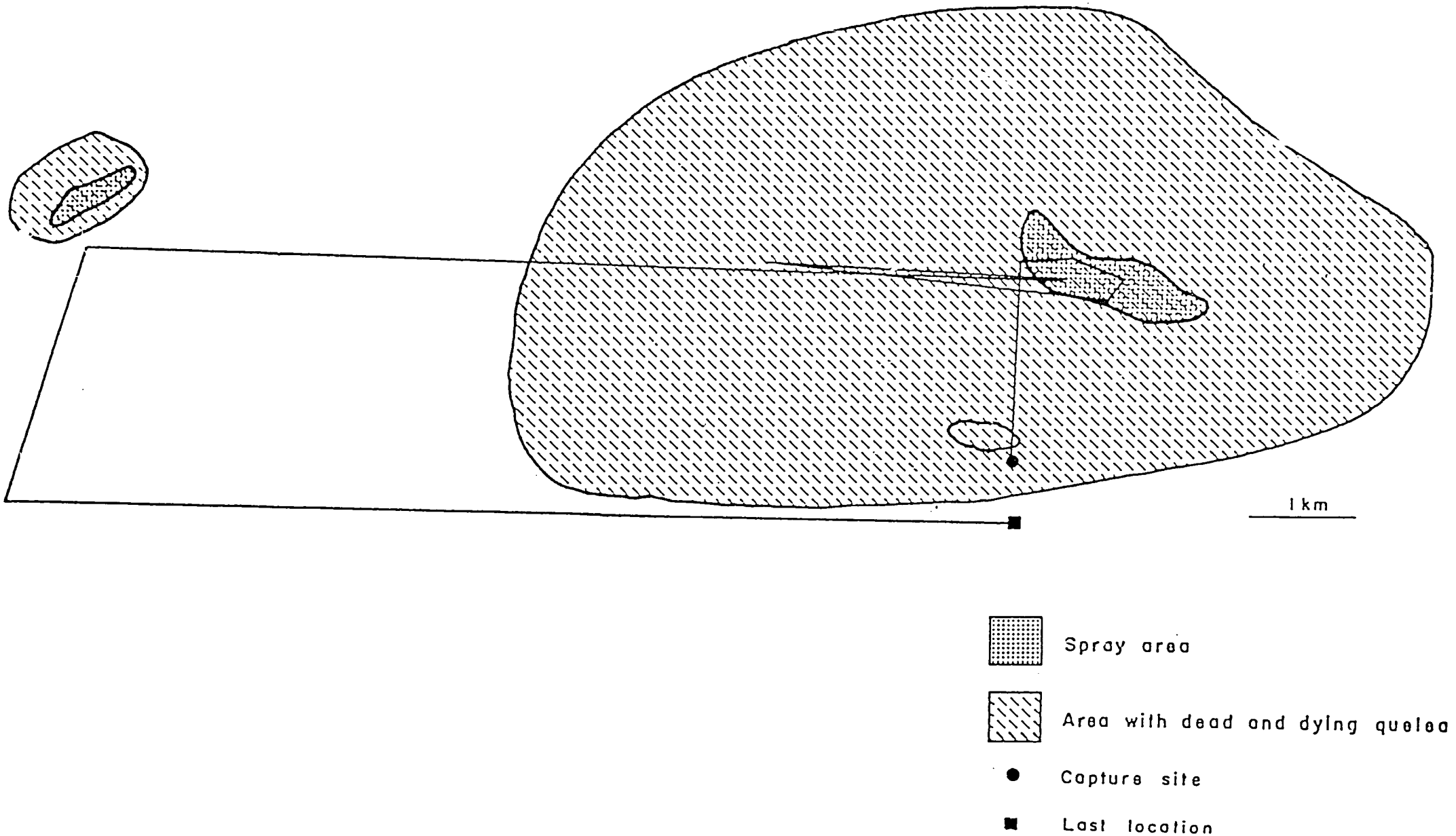
APPENDIX Vd. Movements of pearl-spotted owlet No. 2. The owlet was found moribund 1 day postspray.



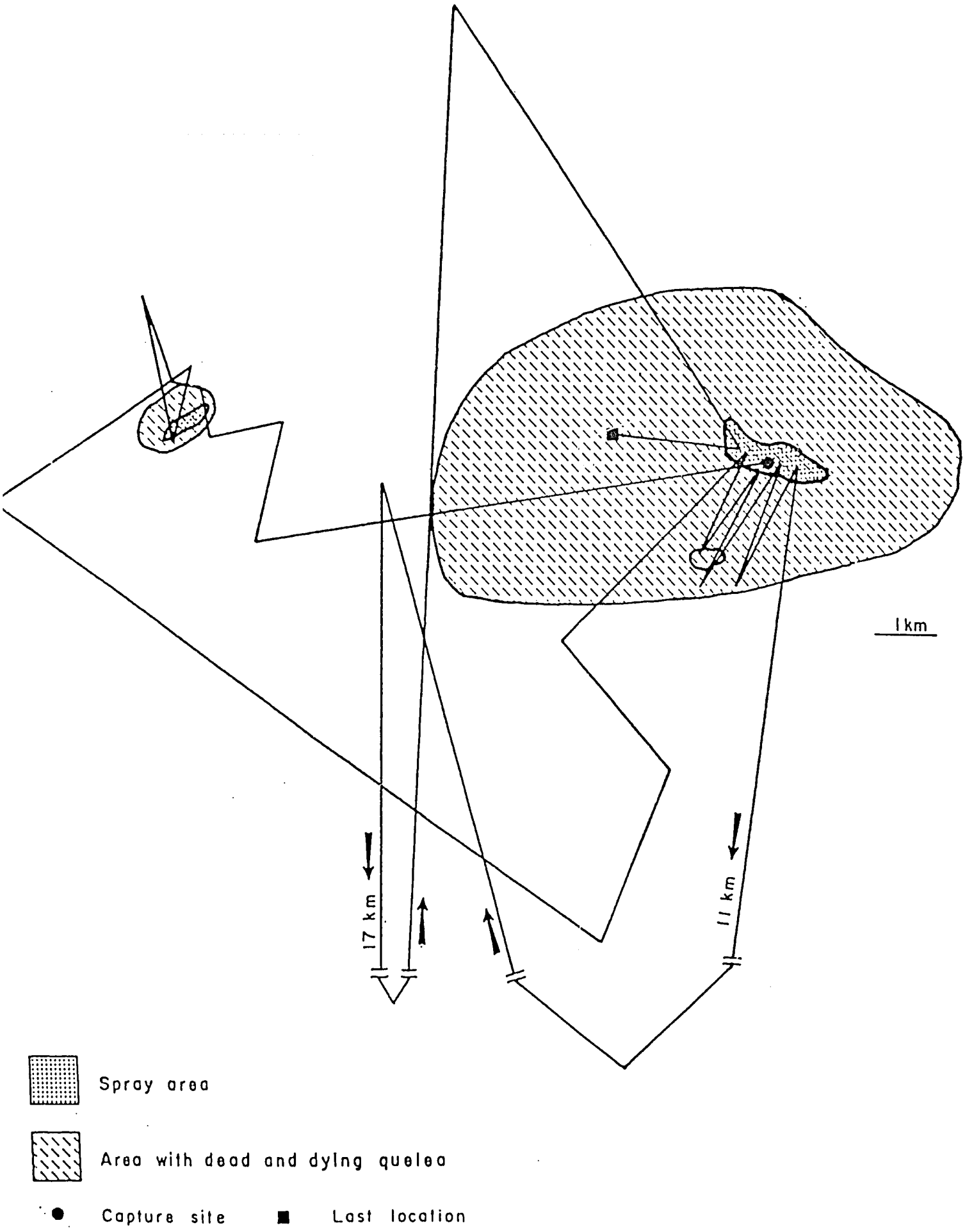
APPENDIX Ve. Movements of tawny eagles Nos. 3, 4, 6, and 8. All movements are postspray (25 April for Crocodile Colony).



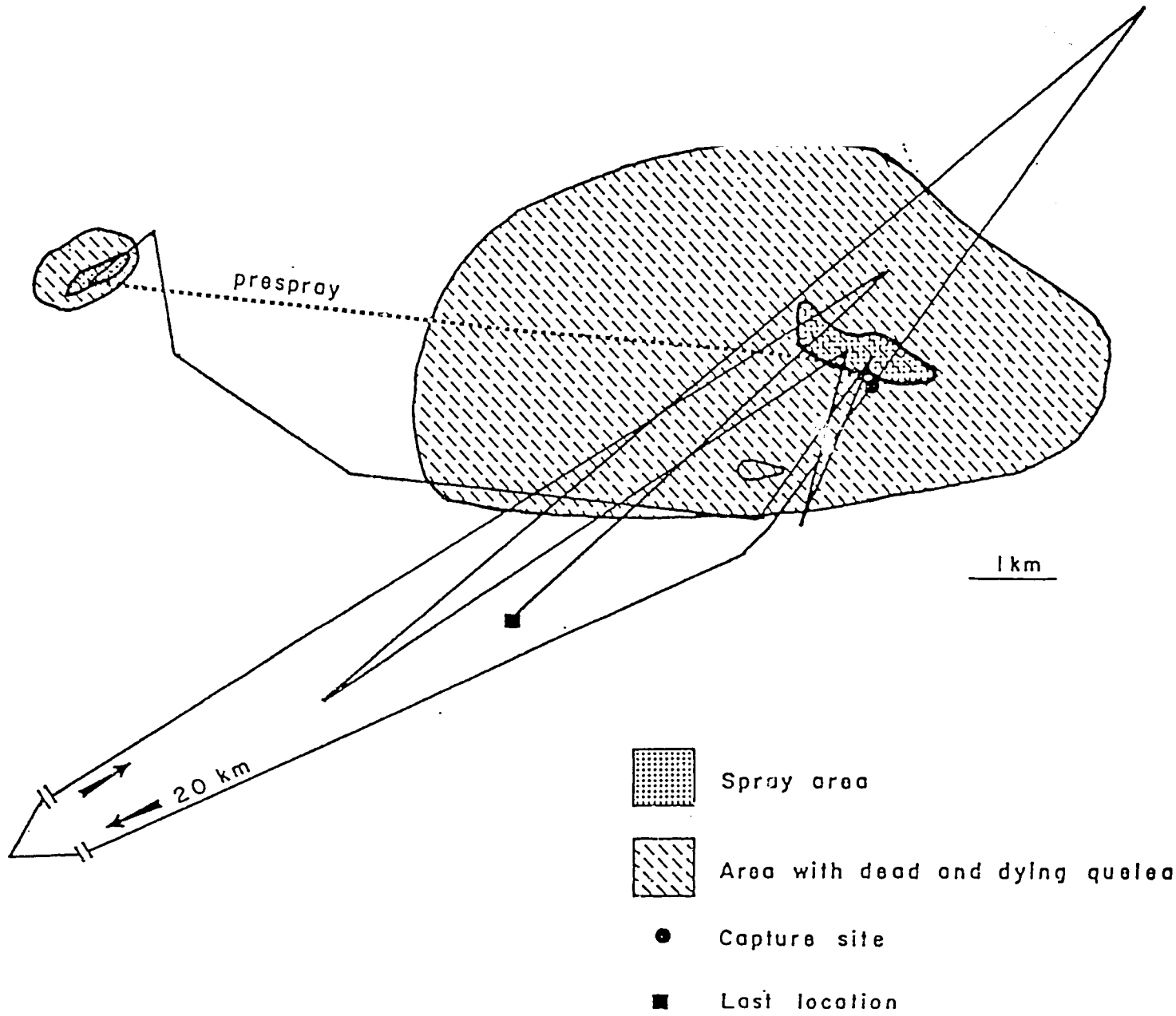
APPENDIX Vf. Movements of tawny eagle No. 5. All movements are postspray (25 April for Crocodile Colony).



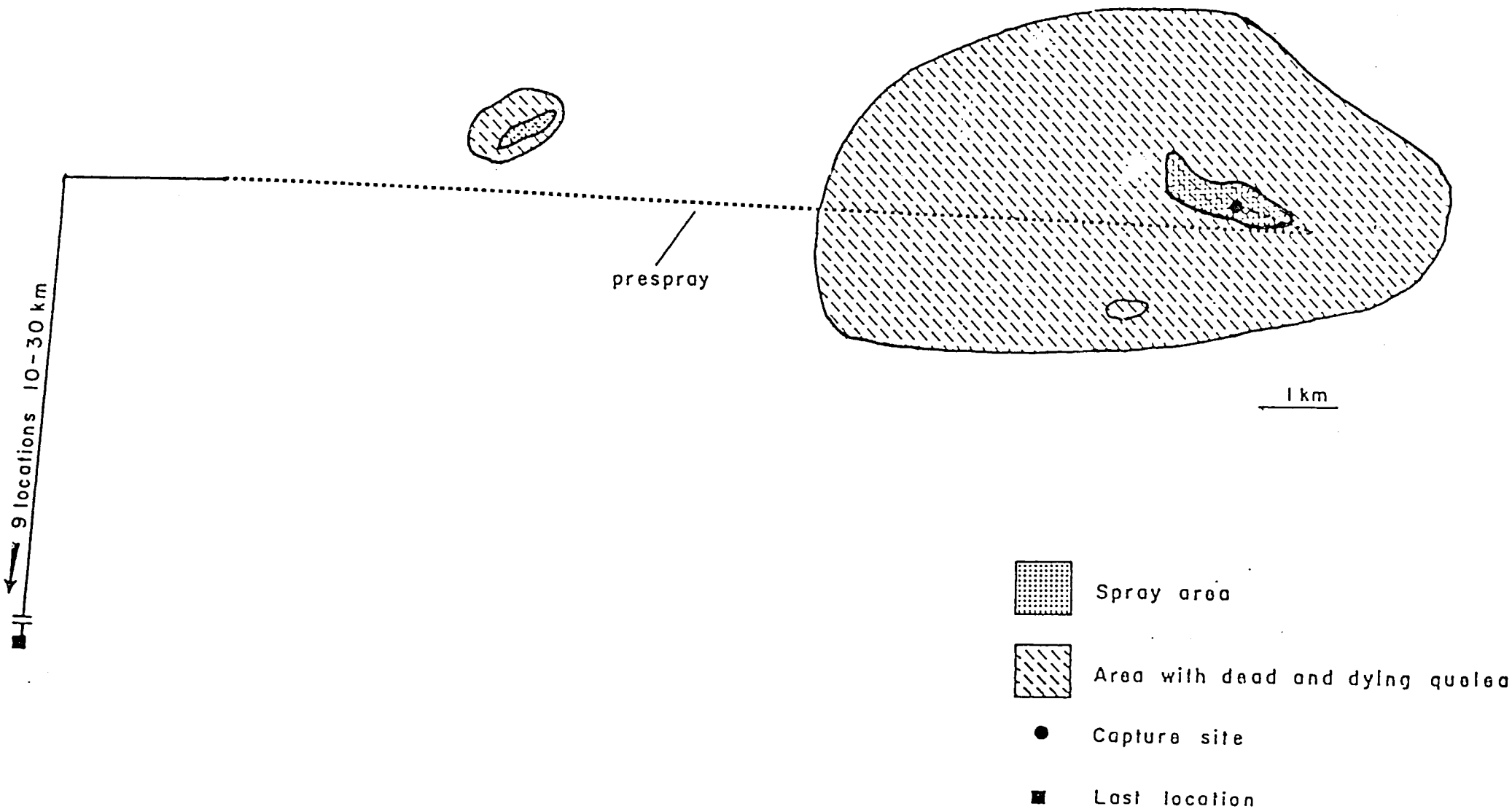
APPENDIX Vg. Movements of tawny eagle No. 9. All movements are postspray (25 April for Crocodile Colony).



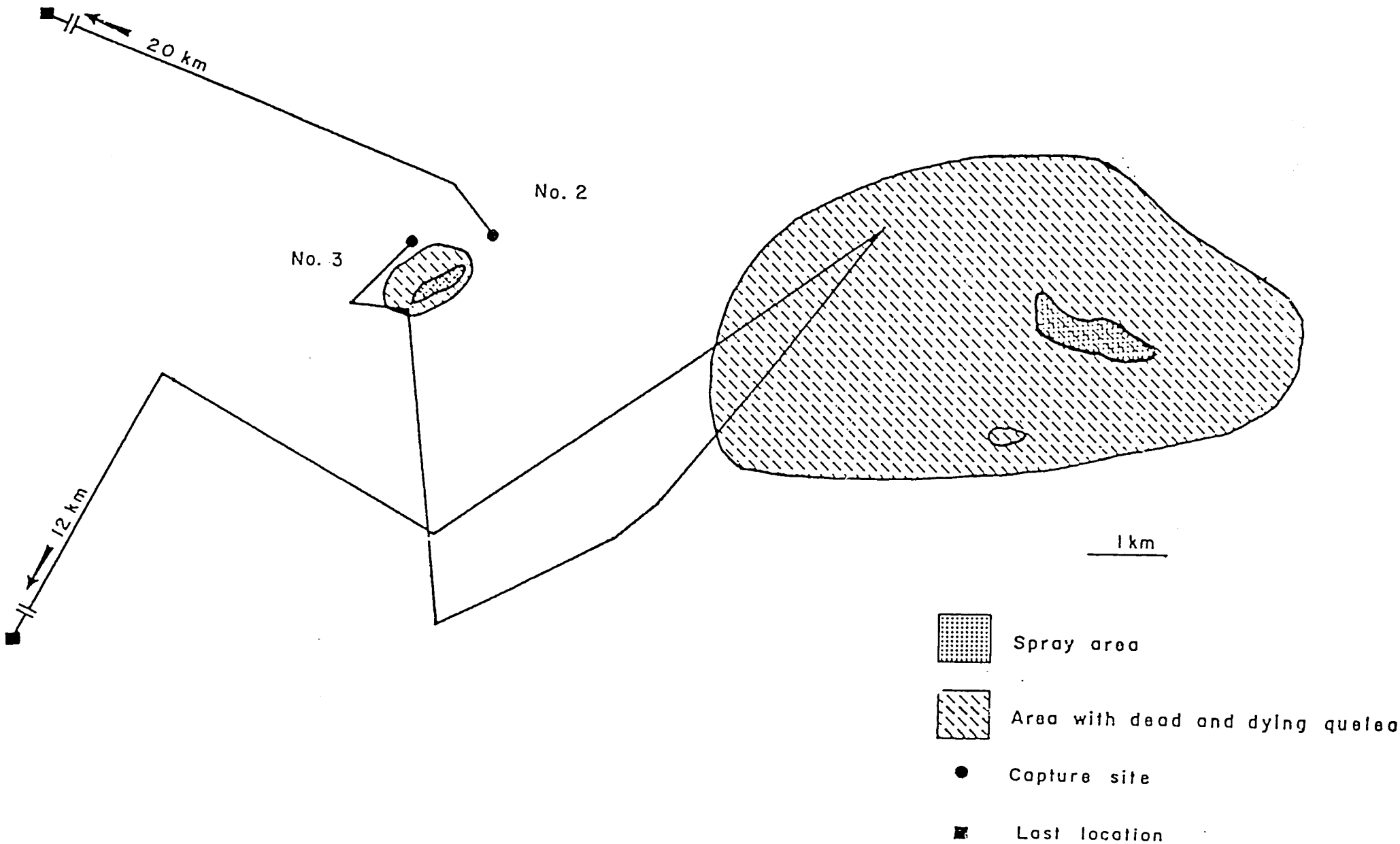
APPENDIX Vh. Movements of tawny eagle No. 10. All movements are postspray (25 April for Crocodile Colony) except as indicated.



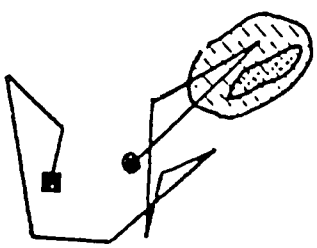
APPENDIX Vi. Movements of tawny eagle No. 11. All movements are postspray (25 April for Crocodile Colony) except as indicated.



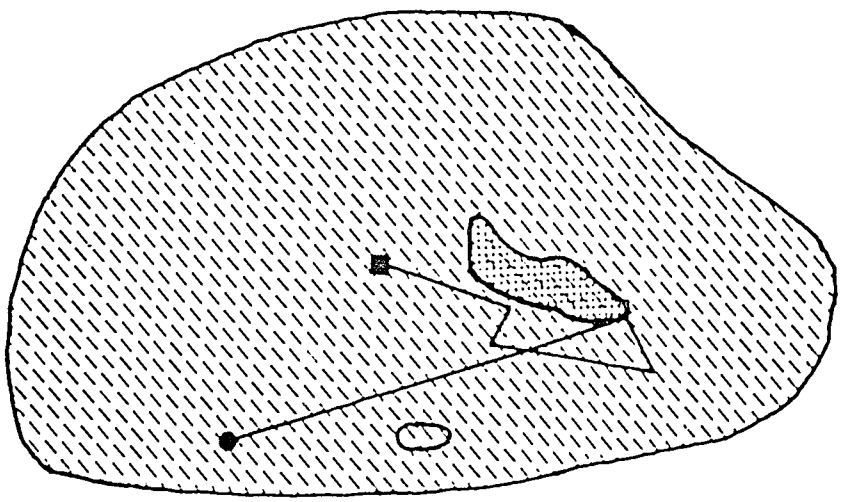
APPENDIX Vj. Movements of bateleur eagles Nos. 2 and 3. All movements are postspray (25 April for Crocodile Colony).



APPENDIX Vk. Movements of pale chanting goshawks Nos. 1 and 3. All movements are postspray (25 April for Crocodile Colony, and 4 May for Ranch Colony).



No. 3



No. 1

1 km

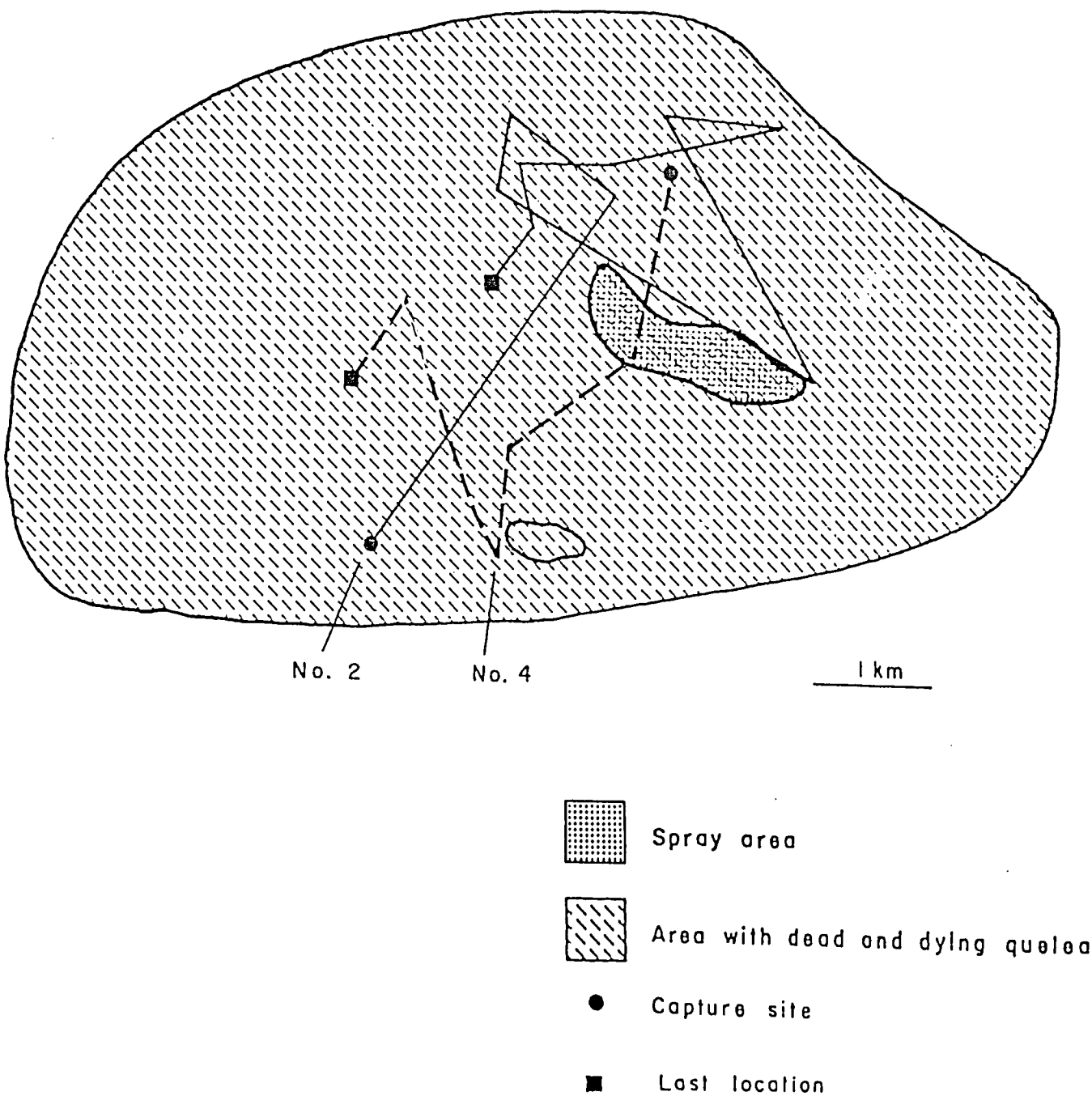
Spray area

Area with dead and dying quelea

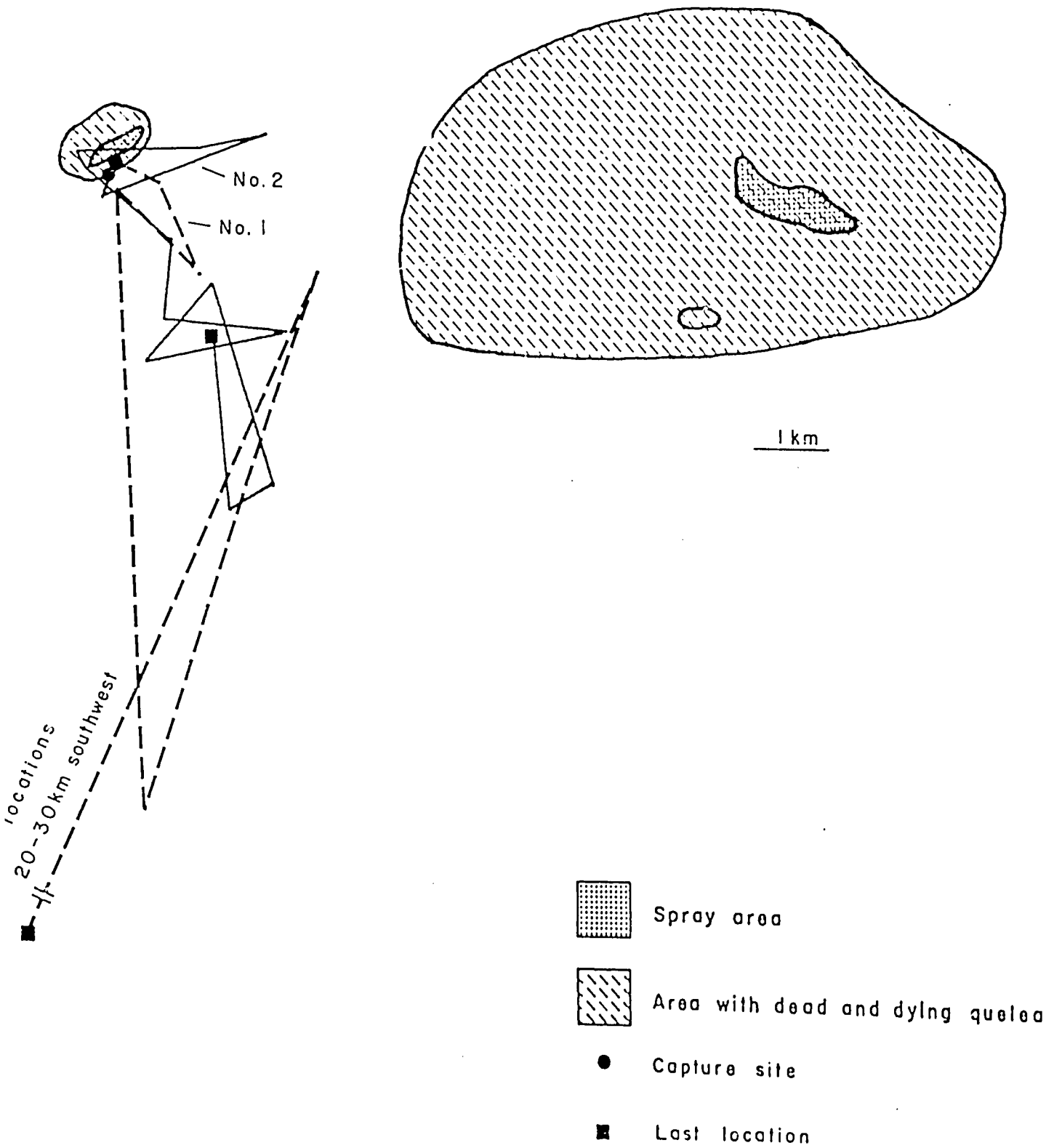
Capture site

Last location

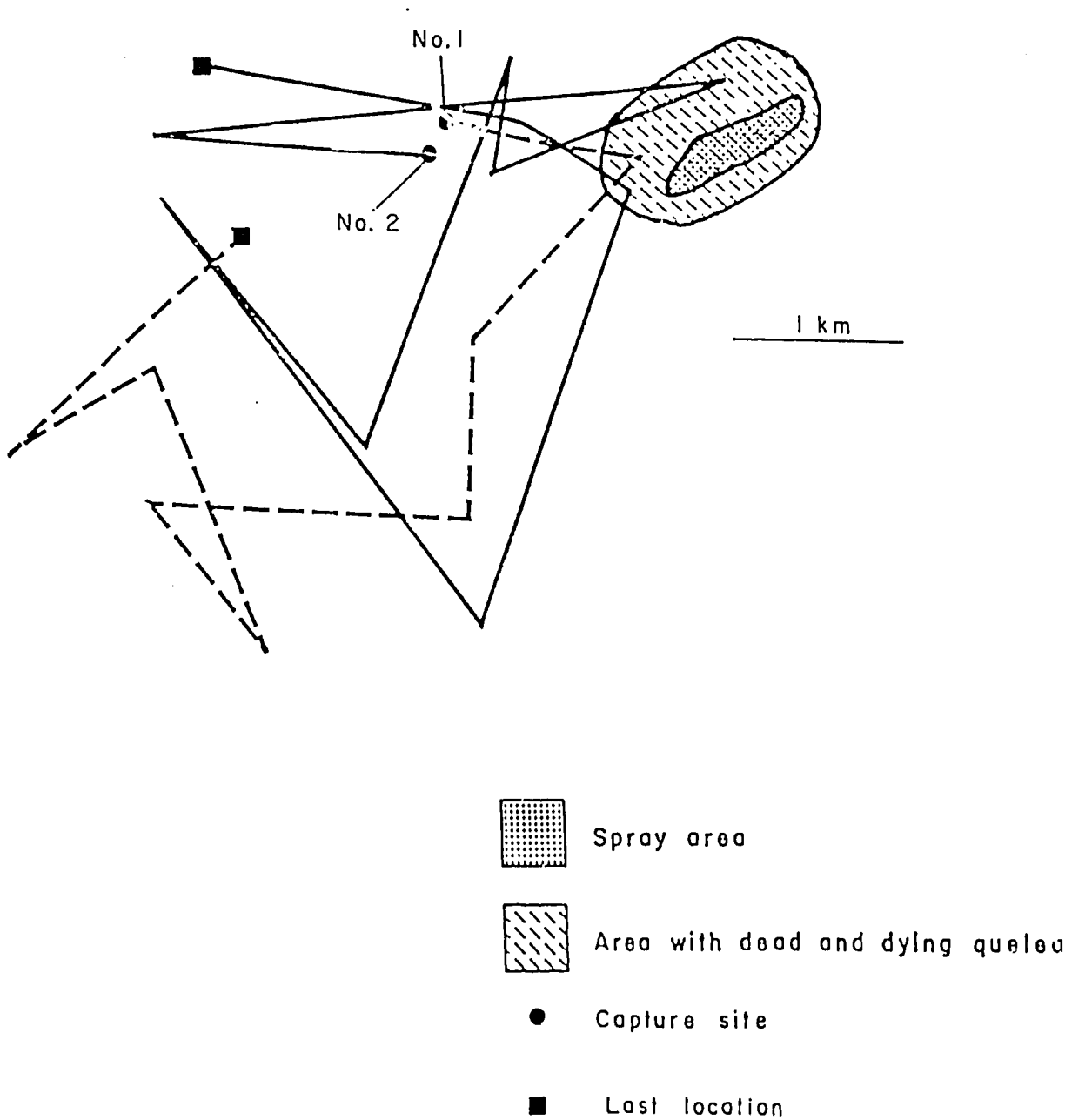
APPENDIX VI. Movements of pale chanting goshawks Nos. 2 and 4. All movements are postspray (4 May for Ranch Colony).



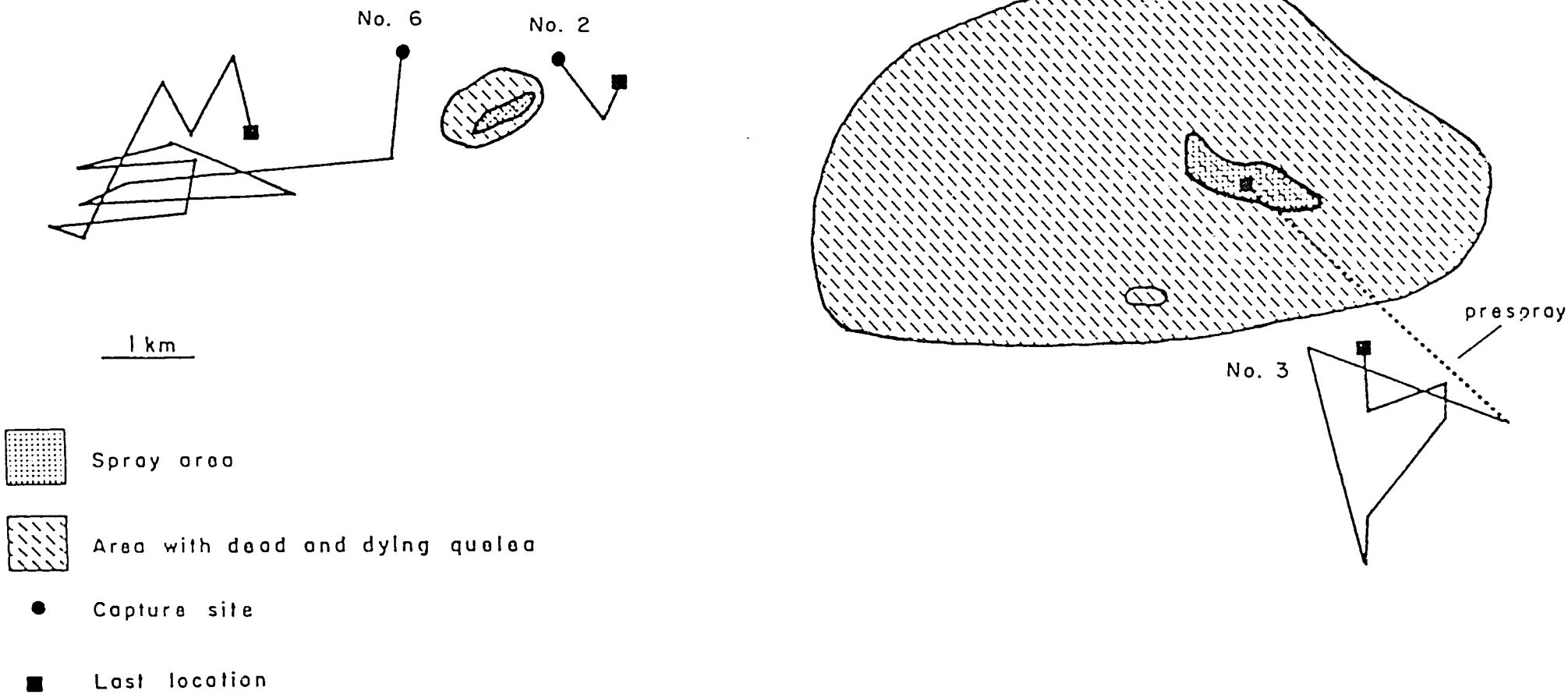
APPENDIX Vm. Movements of gabar goshawks Nos. 1 and 2. All movements are postspray (25 April for Crocodile Colony).



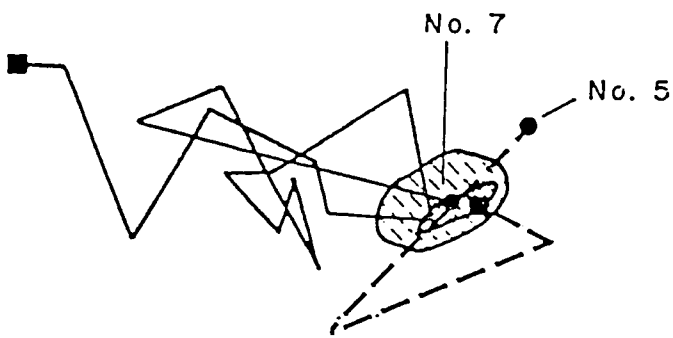
APPENDIX Vn. Movements are pygmy falcons Nos. 1 and 2. All movements are postspray (25 April for Crocodile Colony).

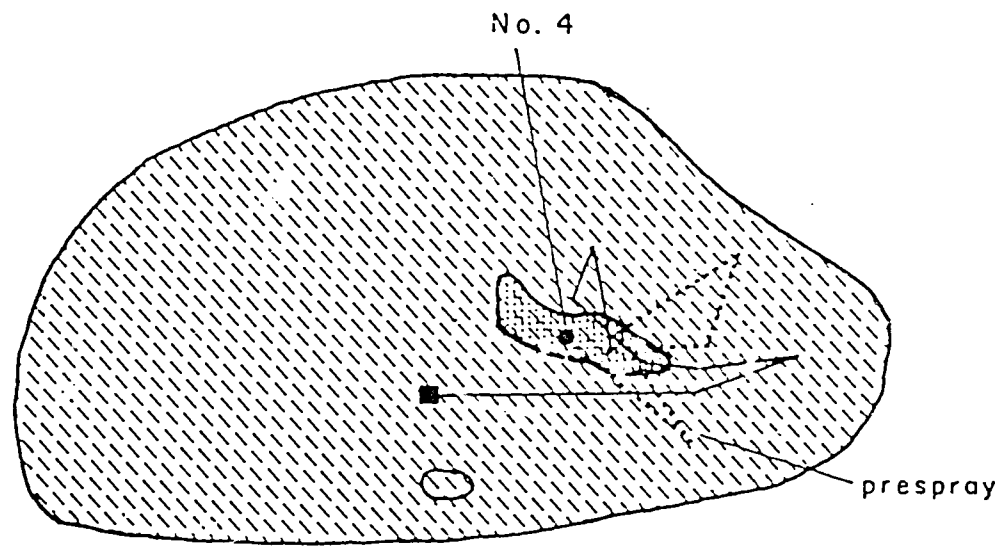


APPENDIX Vo. Movements of black-backed jackals Nos. 2, 3, and 6. All movements are postspray (25 April for Crocodile Colony and 4 May for Ranch Colony) except as indicated for No. 3.



APPENDIX Vp. Movements of black-backed jackals Nos. 4, 5, and 7. All movements are postspray (25 April for Crocodile Colony and 4 May for Ranch Colony) except as indicated for No. 4.





1 km

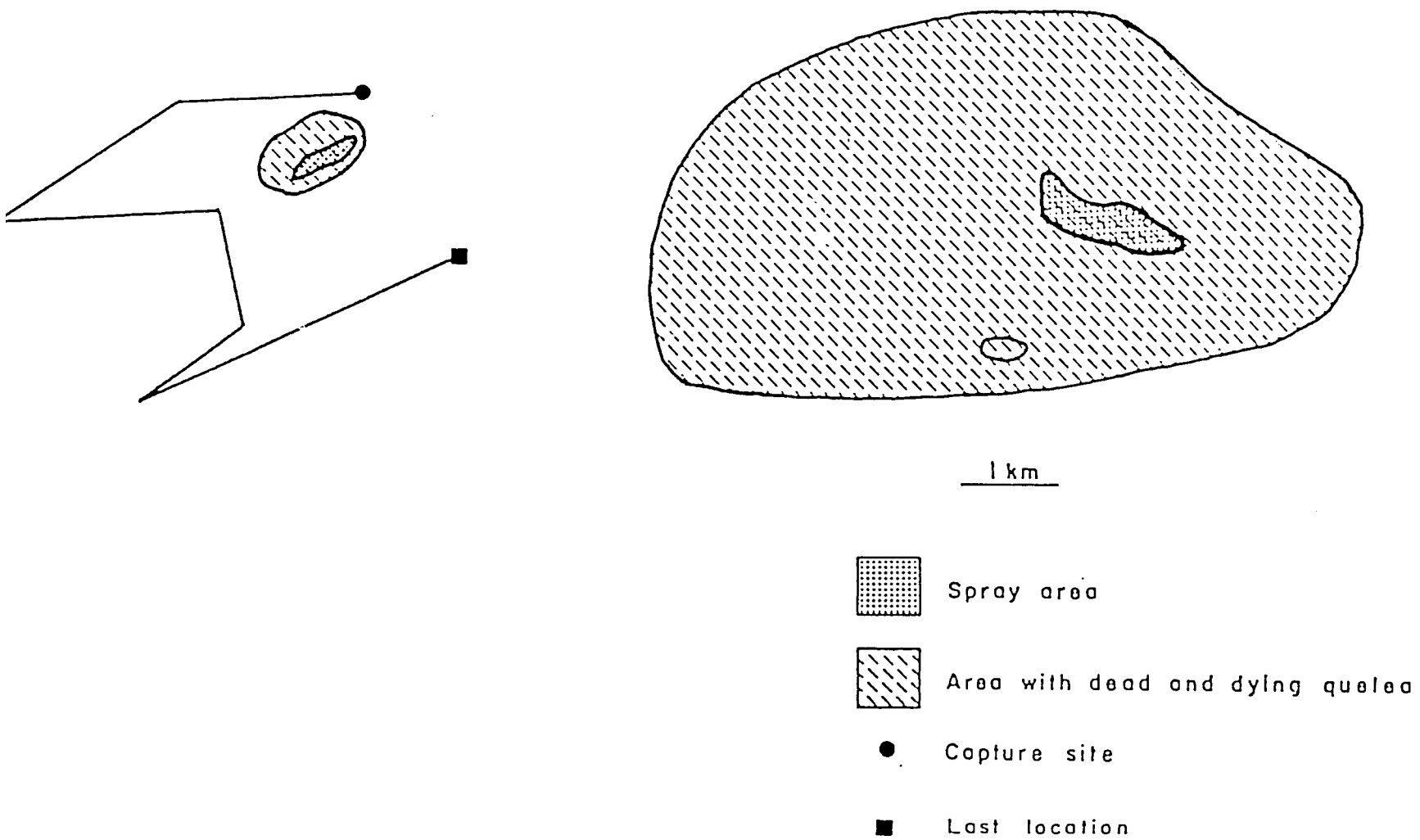
Spray area

Area with dead and dying quelea

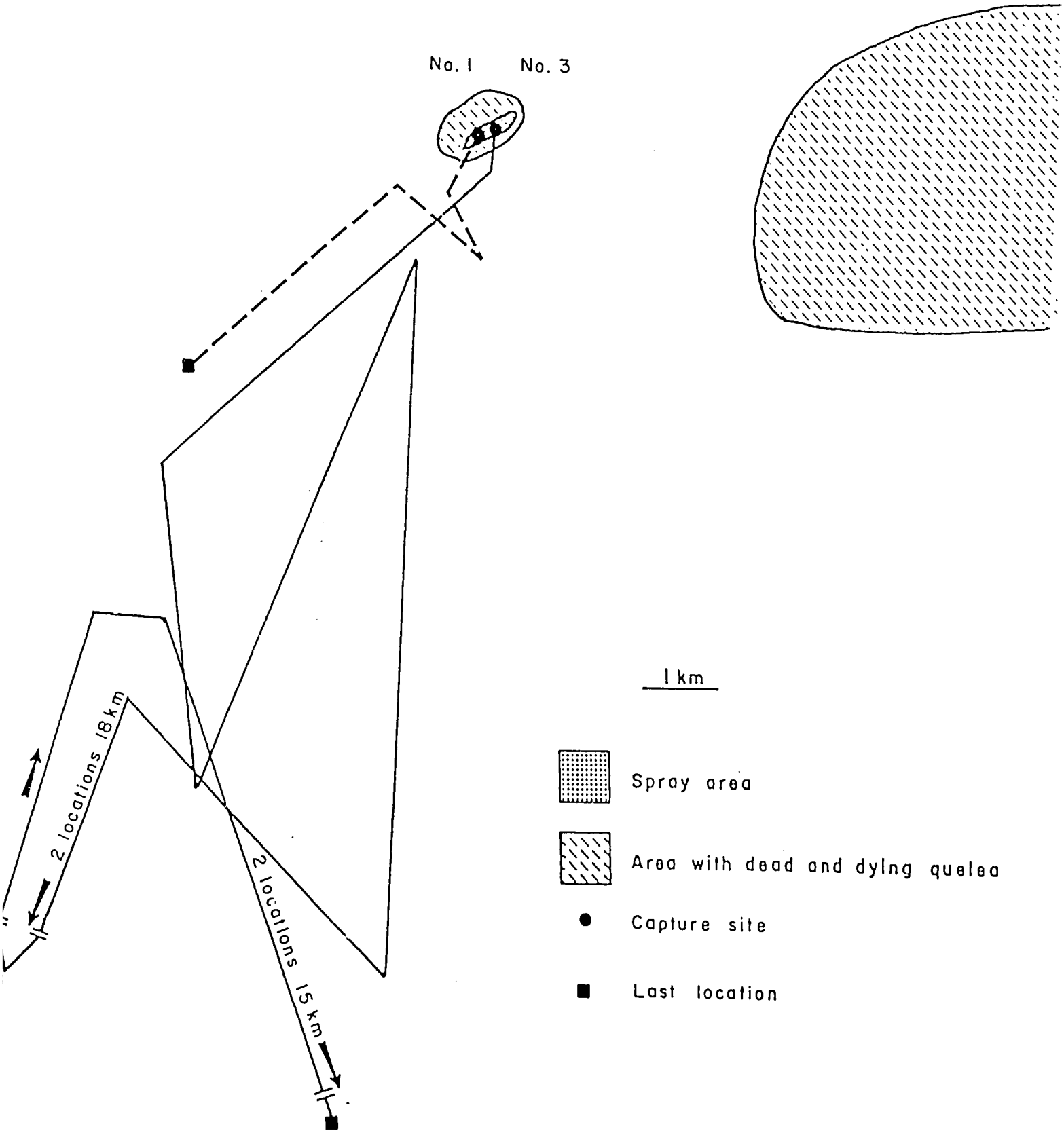
Capture site

Last location

APPENDIX Vq. Movements of common genet No. 1. All movements are postspray (25 April for Crocodile Colony).



APPENDIX Vr. Movements of doves Nos. 1 and 3.. All movements are postspray (25 April for Crocodile Colony) except as indicated.



APPENDIX Vs. Movements of dove No. 2. All movements are postspray (25 April for Crocodile Colony) except as indicated.

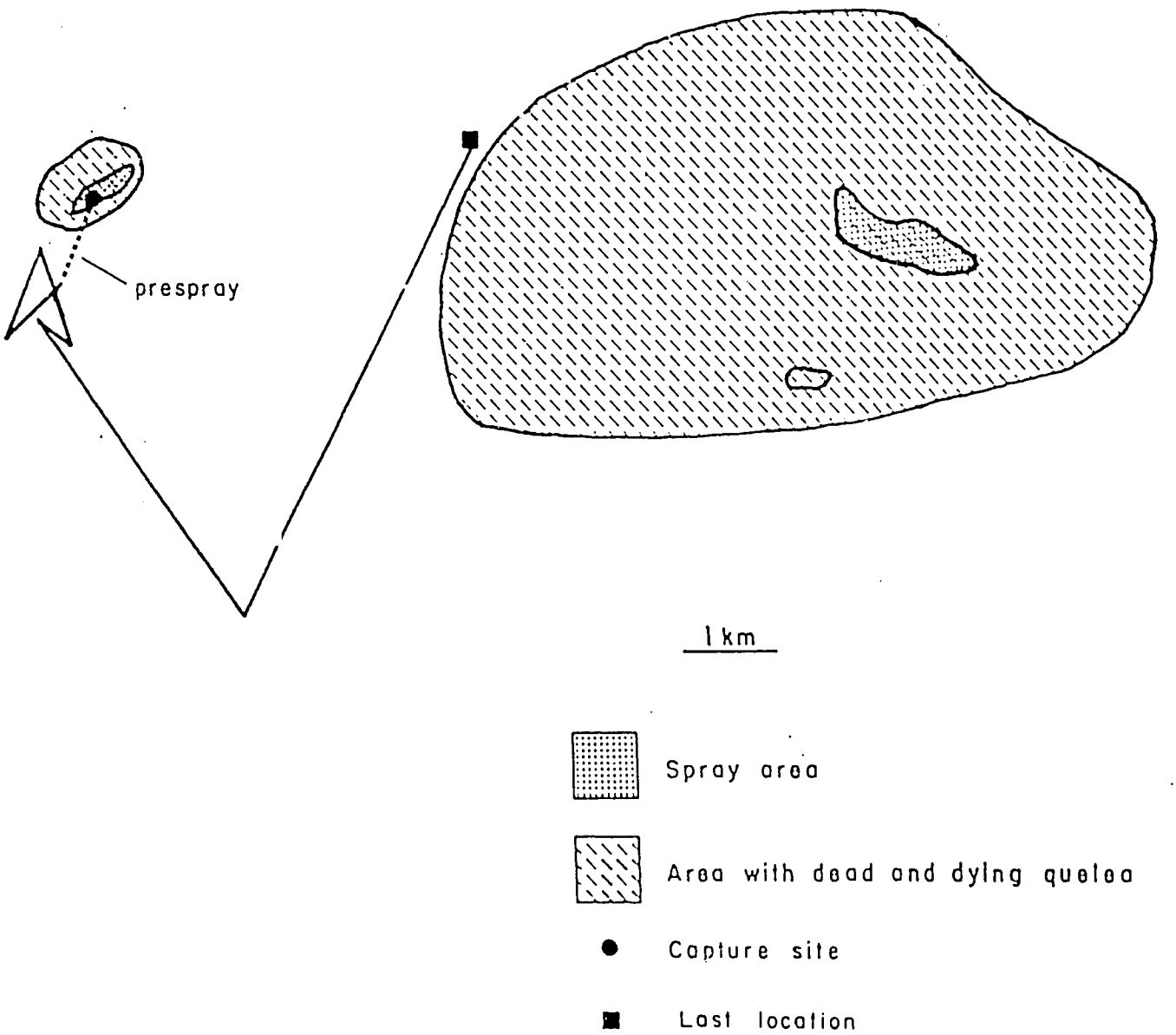


PHOTO CAPTIONS

1. A field camp was established along the Galana River, Kenya, to evaluate the impact on nontarget wildlife of quelea control in two nesting colonies.

2. Raptors regularly feed on young in quelea colonies before and after control operations.

3. & 4. A variety of nooses and snares were built to trap raptors.

5. & 6. Bal-chatri and pole traps also were employed to trap raptors.

7. & 8. Miniature radio transmitters were attached to the base of the tail of quelea and raptors to determine their location postspray.

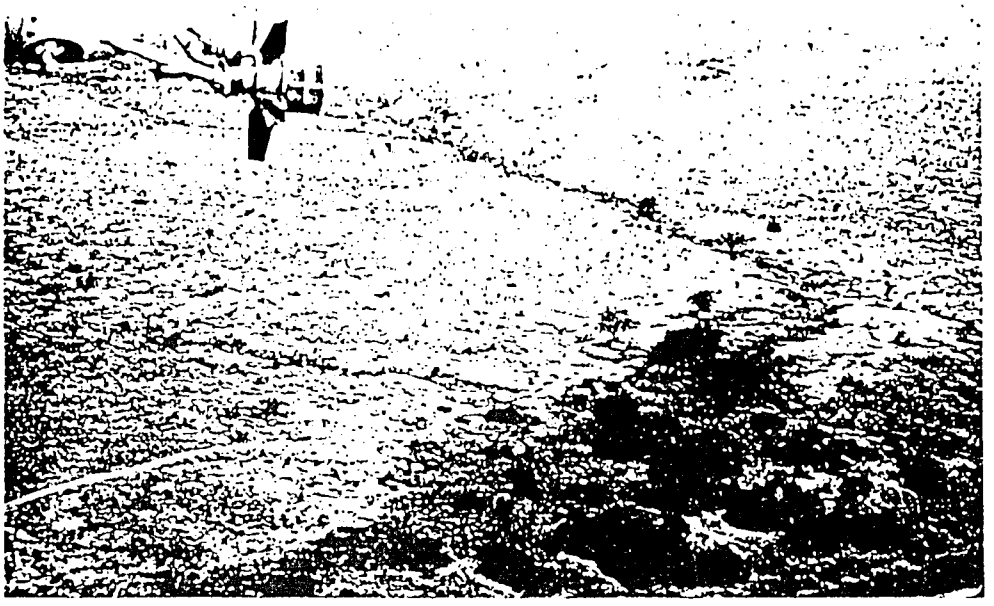
9. Blood samples were taken from captured animals before and after sprays to determine changes in cholinesterase levels and hence esposure.

10. Samples were prepared in a field laboratory for later analyses in laboratories at DLCO-EA and DWRC.

11. & 12. Radio-equipped birds were tracked from the ground and from the air.

13. Spray droplet patterns and residue levels were determined from droplet cards and filter papers.

14. Disappearance rates of debilitated birds by scavengers were determined along a meandering transect within the colonies.



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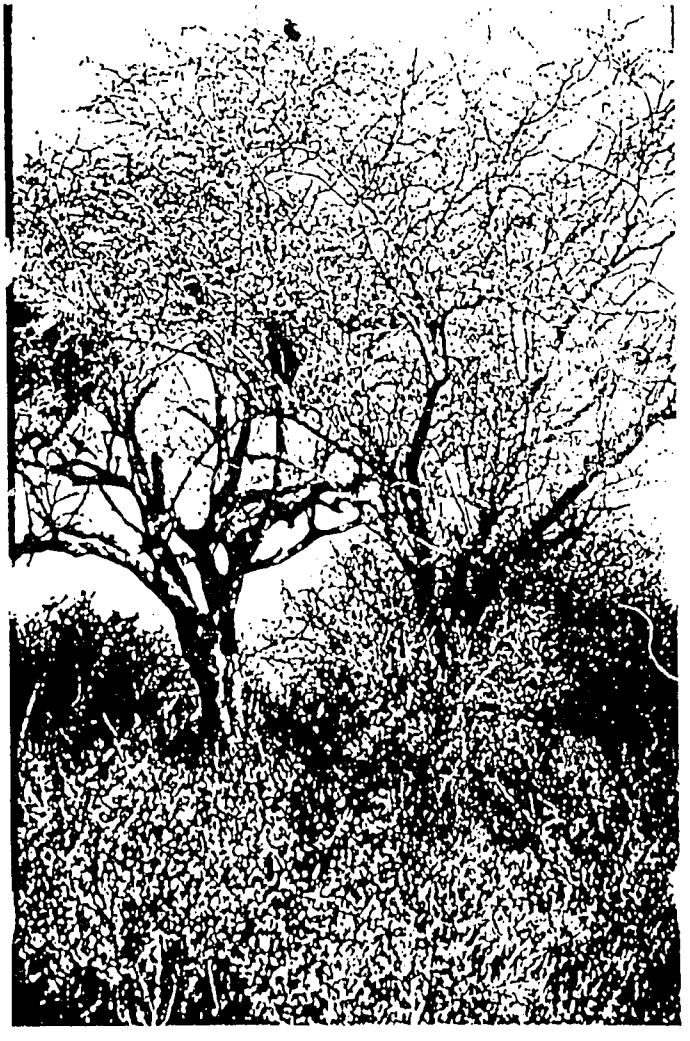

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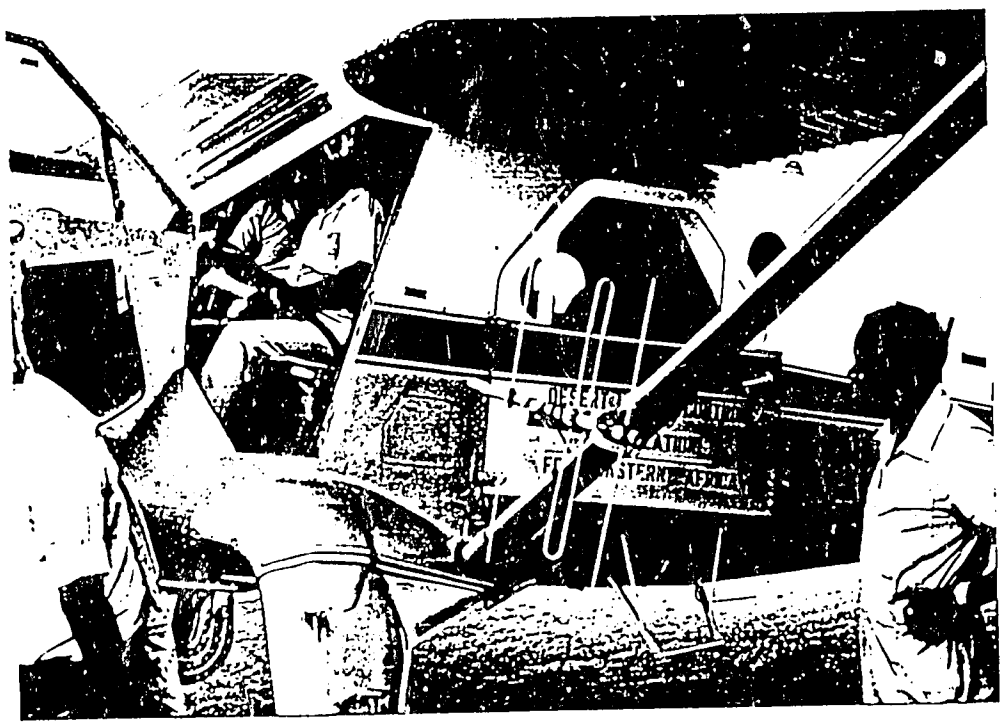
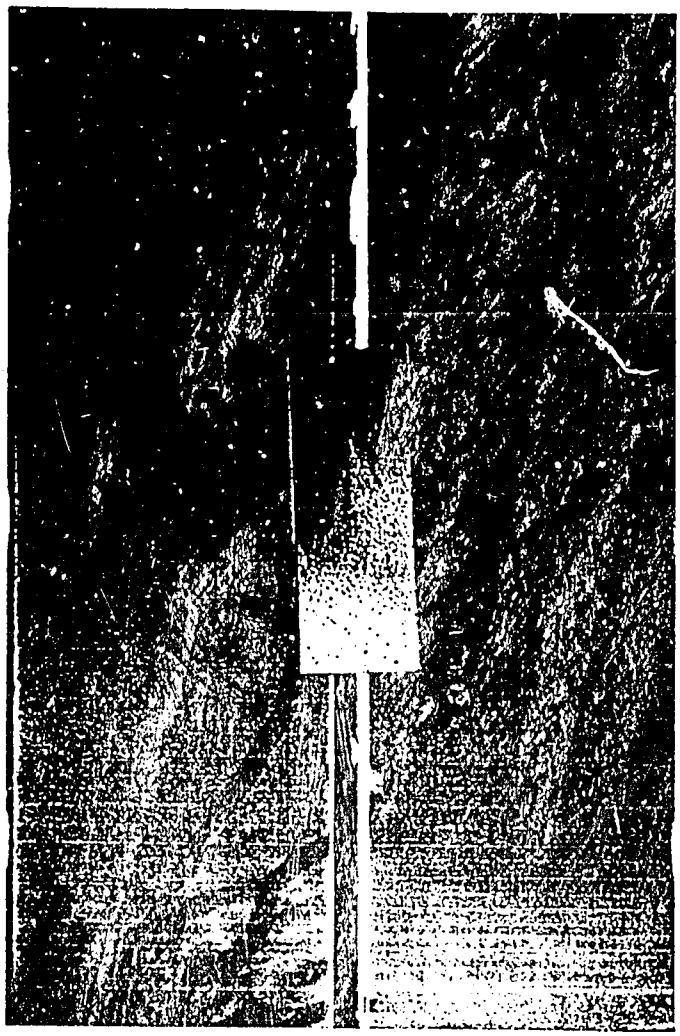
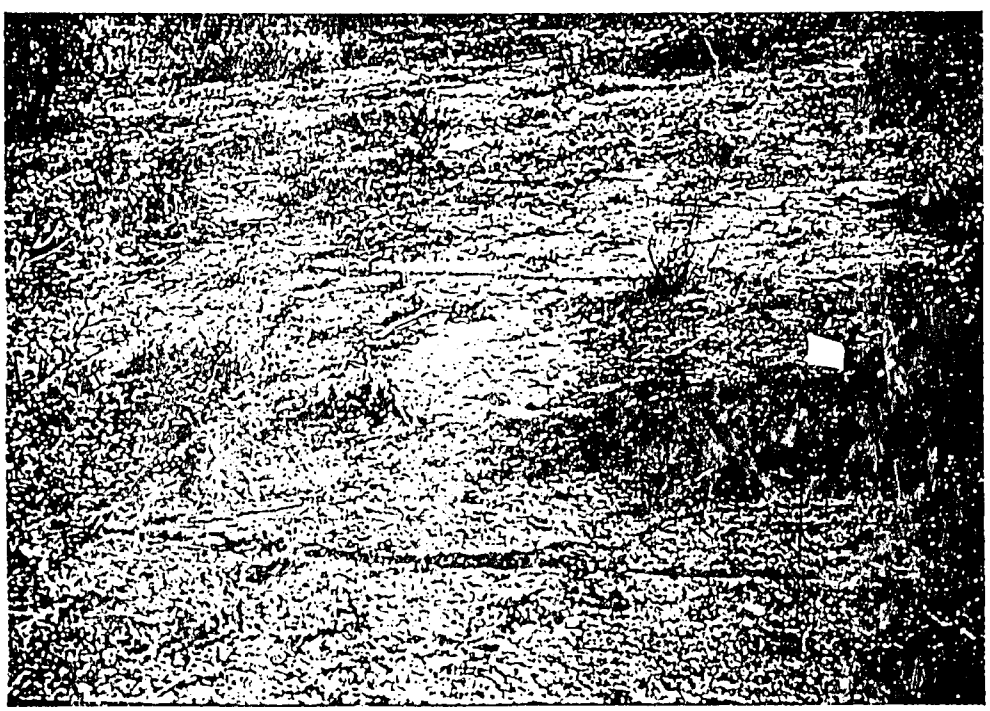


Radio-equipped birds were tracked from the ground and from the air.



Spray droplet patterns and residue levels were determined from droplet cards and filter papers.



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