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Rational Strategies for the Control of Queleas and Other Migrant Bird Pests in Africa [and Discussion]

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Rational strategies for the control of queleas and other migrant bird pests in Africa

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The red-billed quelea, *Quelea quelea*, a major pest of cereal crops in Africa, has been 'controlled' in many countries for over 20 years. Yet its numbers do not appear to have altered significantly in consequence. Low rainfall, which adversely affects the supply of the birds' natural food (wild grass seeds), can be held responsible for the temporary decline in numbers in South Africa between 1955 and 1963, and for the currently reduced population in the Sahel states.

Attempts to make the population reduction strategy effective by increasing the control effort are likely to be unsuccessful and costly. Instead, other crop protection strategies should be selected, each appropriate to particular damage situations. Where damage is caused to irrigated crops in the dry season, or to wet season crops grown along the birds' migration routes, an alteration of crop phenology strategy is appropriate. But where damage is caused by newly independent young, the destruction of nearby breeding colonies is required. Such destruction should aim to give local and temporary relief and not attempt overall regulation of the pest's population.

Neither scaring techniques (including chemical repellents), nor so-called bird-proof varieties, offer much hope, since damage is largely caused by birds which have no alternative, natural, food source at the time.

Other bird pest species require substantial biological research before logical decisions on strategy can be made.

1. Introduction

There are no reliable, nationwide estimates of damage caused by the many bird species that raid cereal crops in Africa. However, there is no doubt that heavy, often catastrophic, losses occur locally and spasmodically throughout the continent. Damage to millet (*Pennisetum*) and guinea-corn (*Sorghum*) has presumably been occurring since their cultivation began, but the introduction of rice and wheat has increased both the diversity of pest species and the amount of damage. Maize is not yet subject to widespread attack, but in several areas, as far apart as Nigeria, Zaire, Somalia and Tanzania (personal observations), various *Ploceus* species have recently learned how to reach the grain; this ability may well spread.

Many weaver-birds and sparrows (Ploceidae) are pre-adapted to raiding cereal crops, for they have evolved in natural grassland or savanna regions where they rely on the seeds of Graminae for the bulk of their food. Those species are particularly important which feed on the seeds of annual grasses growing in low-rainfall regions. Such seed is produced in vast amounts during the wet season and is available during the dry season as fallen seed on the ground. Because of the abundance of food the population densities of these species can be extremely high, making them spectacular and readily identifiable pests. Examples are the red-billed quelea (*Quelea quelea*) in semi-arid regions throughout tropical Africa, the golden sparrow

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(*Passer luteus*) in the Sahel, and Rüppell's weaver (*Ploceus galbula*) along the Red Sea coast of Eritrea and Somalia. In the wetter savanna regions the diversity of species is much greater and flocks raiding the fields frequently include many species of weaver-birds, sparrows, waxbills, starlings, doves, and other birds. Irrigation schemes are harassed by a particularly wide range of species, including waterfowl, some of which are migrants from Europe (Morel 1968).

So far, most of the control effort has been directed against *Q. quelea*, though in the Sahel states increasing attention is being paid to the golden sparrow and in Tanzania concentrations of chestnut weaver, *Ploceus rubiginosus*, and red-headed quelea, *Quelea erythrops* are sometimes destroyed.

Operations against *Q. quelea* are currently undertaken in some 16 African states and prodigious numbers of birds – up to 1000 million annually – are being killed. The strategy being pursued is apparently aimed at overall population reduction, though this is rarely spelled out. Over the 25 years since quelea control operations began there have been many tactical improvements and a general evolution from ground-based techniques (physical nest destruction, explosives, flame throwers) to aerial application of skin-penetrating organophosphorus poisons. Yet there has been little questioning of the overall strategy, and criticism of this (Ward 1964, 1965*c*, 1972, 1973; Bortoli 1974; Roy 1974) has, so far, been largely unheeded by control organizations.

When control activities began in the 1950s it would have been impossible for the authorities responsible to have made the kind of logical strategy choice to be advocated here, for most of the required biological details, particularly of natural diet and migration, were lacking. Now, however, there is a great deal of relevant information (see especially Williams 1954; Morel & Bourlière 1955, 1956; Morel & Morel 1957; Haylock 1959; Crook 1960; Ward 1965*a*, *b*, 1966, 1971; Jones & Ward 1976; Ward & Jones 1977). It should therefore be possible to select the best (meaning effective, safe and economic) control strategy for any patricular region by careful consideration of the facts, instead of simply trying to make the original strategy work where it has failed, by increasing control effort.

There is another reason why it is important to re-examine quelea control strategy at this juncture. As the only large-scale campaign operating against birds in the tropics, it is tending to serve as a model which could well be emulated as a way of dealing with other pest species in Africa, Asia and Latin America.

2. Outline of the biology of *Quelea quelea*

Red-billed queleas occur throughout the semi-arid regions of tropical Africa (see figure 1). They are highly gregarious, feeding in flocks of hundreds or thousands, and assembling at night (when they are not breeding) in communal roosts which often hold millions of individuals. The roosts are situated in dense groves of trees, reedbeds, papyrus or other thick cover and a typical site is occupied for only a few weeks before the birds move on in their quest for good feeding places. Where suitable vegetation is widespread it is not possible to predict in advance where roosts will be established, but where man has cleared all but a few dense patches of vegetation these are used regularly. In such situations it often happens that after a successful control operation, in which most birds are killed, the site fills up again within a few weeks (personal observations in Tanzania), indicating that a communal roost is a dynamic situation with individuals joining and leaving all the while. Each morning the queleas leave their roost site in flocks which often travel long distances (up to 50 km) to feed. Feeding is intense during the first three hours of the day after which the flocks assemble in patches of dense vegetation, invariably near water. In these day roosts, or 'secondary roosts' (Ward & Zahavi 1973), they rest in the shade and drink frequently throughout the hot hours of the day. A second feeding session in the late afternoon precedes their return to the 'primary' roost at dusk. This pattern of feeding, which allows the birds to exploit an unevenly distributed food supply, is made possible by their possessing a highly distensible oesophagus which serves as a food reservoir. Thus, although feeding time may be only 5 hours or less each day, a continuous flow of food into the stomach is maintained throughout the mid-day period in the secondary roost and also for a few hours after dusk. In one study in Tanzania (Ward 1978) some three-quarters of the day's food was collected in the morning feeding session and this is probably the normal pattern.

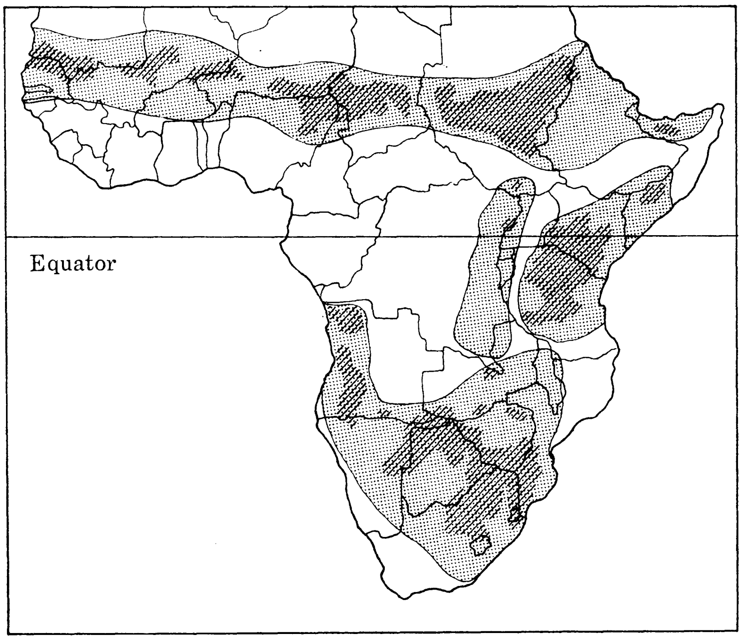

FIGURE 1. Generalized distribution of *Quelea quelea* (Compilation of original data by J. I. Magor). Note: the main breeding areas (hatched) are variable in extent depending on annual rainfall; important areas probably remain to be discovered.

Breeding takes place during and shortly after the wet season. Large, highly synchronous colonies are established in similar situations to those used for communal roosting. The sites change from year to year and cannot be predicted.

Seasonal changes in the diet of *Q. quelea* have been studied in Nigeria (Ward 1965*a*) and in general appear to be similar throughout Africa. During the dry season the food consists almost entirely of the seeds of grasses, mainly the small seeds of *Panicum*, *Echinochloa*, *Brachiaria* etc. and the larger seeds of wild rice (*Oryza barthii*) and wild sorghum (*Sorghum* spp.) Wheat and rice, left on the ground after mechanical harvesting, may feature prominently in the diet in a few, relatively small, areas; cereal crops grown under irrigation, or on receding floods, and maturing in the dry season, are frequently attacked. This does not indicate a preference by the birds, for in many situations ripening cereals are ignored by large flocks of *Q. quelea* feeding nearby on wild grass seeds.

During the wet season also, grass seeds constitute the major item of diet and colonies are established close to areas of maturing annual grasses growing in flooded depressions. Insects also feature prominently in the diet during the rains, providing an indispensible source of the protein required by the breeding adults (especially the females) and young (Ward 1965 *b*, Jones & Ward 1976). After successful breeding, flocks of juveniles, abandoned by their parents, search for seeds near the colony; any maturing cereal crops in the neighbourhood are then extremely vulnerable.

So far the seasonal pattern has been described as if the populations were simply highly mobile within fixed areas (i.e. nomadic), but superimposed on this is a regular migration system. The migration patterns have been worked out partly on the basis of observed displacements (Haylock 1959) and data obtained by ringing (Rowan 1964), but mainly from predictions based on rainfall chronology (Ward 1965 *a*, 1971) and subsequent surveys. The basic reason for the migration is the dependence of the species on the seeds of wild grasses which are available for most of the year on the grass heads or on the ground, but not during the six weeks between the onset of prolonged rain, when the seeds on the ground germinate, and the beginning of seed formation by the new grass plants (Ward 1965 *a*).

As the seeds disappear at the start of the rains the queleas put on pre-migratory fat, the amount being correlated with the distances to be flown; the races *intermedia*, *lathami* and *quelea*, which migrate 1200, 550 and 300 km respectively, lay down 3–4 g, 2–2.5 g and 1.5–2 g of fat (Ward & Jones 1977). The direction flown on this 'early-rains migration' is towards areas where rain has been falling for some 6 weeks and where, therefore, fresh grass seed is becoming available. How they navigate towards the 'early-rains quarters' is not known, but they may simply travel up wind. They are not heading for any precise destination and at this time the prevailing wind is opposite to the direction of displacement of the rain front. The actual compass direction taken by the different quelea populations on their early-rains migration varies greatly (see Ward 1971).

The birds arriving in the early rains quarters are in a wide variety of physiological conditions and small breeding colonies may be established by the more precocious individuals. However, the majority remain for only a few weeks before returning in the direction from which they came, moving now with the wind (and perhaps guided by it) and with the slow tide of grass maturation in association with which they can breed. Large colonies are established in the course of this return 'breeding migration'. There is strong circumstantial evidence that individuals which have completed breeding operations in one area can move quickly to catch up with the tide again and begin another brood. This procedure, termed 'itinerant breeding' (Ward 1971), may allow (in a favourable year) two broods to be raised in succession in the Sudano – Sahelian belt, three or four broods in southern Africa and up to five broods in East Africa.

3. Present control strategy

The aim of most control organizations operating against the red-billed quelea is simply to locate as many concentrations of birds as possible, and to destroy them. The destruction may be carried out efficiently, but it is probable that only a small proportion of the concentrations within the vast area each population occupies are ever located. Breeding colonies are easily seen from low flying aircraft, but the logistics of complete air coverage of a whole population's breeding range are formidable. For example, in years when the rains are good the area within which breeding colonies could be established by the southern African *lathami* population is 6 000 000 km^2, that of east African *intermedia* 600 000 km^2. Moreover, a complete survey must

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be carried out twice during the wet season, for an early survey will miss colonies established subsequently, and a late survey will discover the early-established colonies too late to permit treatment before the site is abandoned.

As emphasized earlier, the location of breeding colonies cannot be predicted in advance, especially in sparsely inhabited country where suitable patches of dense vegetation are plentiful. Ground support (landing grounds, transport of fuel supplies and provisions) are difficult to provide in large parts of each population's breeding area where there are no passable roads during the wet season (especially in wet years when breeding is most widespread). Moreover, the breeding range of each population covers parts of several independent States, making co-ordinated survey difficult or, in some instances, impossible.

Not surprisingly aerial survey cannot be employed on this scale and colonies are located mainly by scouts or reported by farmers. Consequently, coverage is very uneven, only colonies situated in parts of the population's breeding range where there are farmers aware of queleas, or close to roads travelled by scouts, being found. The *Q. queleas lathami* population, for example, extends into parts of South Africa where there is a complete road network, a farming community 'at risk' from quelea attack, numerous landing grounds, good telecommunications, etc. Colonies formed there are readily located and quickly destroyed. But the same population establishes breeding colonies throughout a vast area of the Kalahari and adjacent thinly populated areas in Botswana, Namibia, Zambia and Angola. Similarly, that part of the population centred on Lake Chad that breeds in northeast Nigeria may be much reduced by the control unit operating there, but this does not apply to colonies established by members of the same population in the much more extensive swamplands of Chad Republic where communications of any kind are extremely tenuous during the rains.

What has been said of the difficulty of locating colonies applies even more strongly to communal roosts. They also are ephemeral and unpredictable, and cannot normally be seen from the air. Although ground travel is easier in the dry season the area to be searched is even larger than during the breeding season.

Clearly the main difficulty of pursuing a 'total population reduction strategy' is the location of a sufficiently high proportion of colonies and roosts to allow a high percentage kill over the whole of a population's total range, every year.

The question which may be posed is 'How large a percentage kill is required for the population size to be reduced to well below the natural level?' Before discussing this it is important to recognize that *Q. quelea* is an opportunistic species. The abundance of its food is governed by the rainfall (Gaston 1976), and since this is erratic in the climatic zones it occupies, it follows that it has a highly variable food supply. Moreover, the food supply is the natural regulator of its numbers, as for most bird populations (Lack 1954). Queleas are not normally subject to intense predation, nor to widespread disease (Barré 1974). Thus, although there is no way at present of monitoring the annual changes in numbers of any one population there are good *a priori* reasons for expecting great fluctuations which are ultimately due to variation in the annual rainfall.

The population dynamics of red-billed queleas are difficult to investigate owing to their mobility and itinerant breeding. By analogy with other small passerines one would expect the average annual mortality of adults to be in the order of 50–60 % (Lack 1954; Rowan 1964). Assuming that mortality results mainly from competition for limited food supplies, notably in the late dry season (see Ward 1965*a*), the destruction of adult queleas in control operations cannot be expected to add to the natural mortality, for it reduces the competition for food among the survivors. In order to make inroads into the population size a percentage kill much higher than the natural annual mortality rate is required. For example, in order to obtain a modest 20% reduction in the population of adults each year, a percentage kill of 75–80% annually over the whole of the population's range might well be required. This crude calculation ignores recruitment to the population of adults from the ranks of the juveniles which might increase as competition for food is reduced, making it even more difficult to lower the population size.

We are left with the daunting fact that in order to reduce the population below the natural level a very high percentage of the adult and juvenile population would have to be destroyed every year. This could be achieved if every single concentration of birds throughout the population's range could be located and attacked with, let us say, 80% efficiency. Alternatively, 80% of the birds could be located provided the control measures were 100% effective. But, as emphasized earlier, the location of such a high percentage of quelea concentrations each year is practically impossible and percentage kills obtained when sites are sprayed are frequently low (personal observations) owing to the difficulties and dangers inherent in the tactics employed.

Notwithstanding the above, let us imagine that, by involving a very large force in a great international campaign lasting for several years, a particular population has been greatly reduced in size. What then? Without doubt some other species would move in, or, if it was already present at low density, would increase in numbers. A bird is most likely, for great mobility is needed for location of the widely-spaced food concentrations during the dry season and for their exploitation. Obvious candidates are the golden sparrow (*Passer luteus*) if a *Q. quelea* population in the Sudano-sahelian were to be 'controlled', and the chestnut weaver (*Ploceus rubiginosus*) if the East African population of *Q. quelea* were to be reduced. In other words the likely replacements in this hypothetical situation would be other granivorous species which at times would be likely to attack cereal crops!

The other major outcome of such an effort would be that a force almost as large as that which brought down the population would be permanently required to keep the population at the desired low level. Roosts and colonies would tend to be small but scattered over the same large area as before.

4. Present quelea control strategy in practice

The longest series of reliable records of a quelea control unit are from South Africa, where roosts and colonies have been destroyed by aerial application of avicides since 1956. As figure 2 shows, the annual kill dropped steadily between 1956 and 1963, and understandably it was felt that control measures had been extremely effective. Since 1963, however, the annual toll has fluctuated wildly and the highest number destroyed to date was in the 1967–8 season, after 13 years of routine control activity. Analysis of the recoveries of *Q. quelea* ringed in the area during the initial decline phase attributed to low rainfall (Jones 1979) indicated that the expected natural mortality rate had hardly been altered by the control efforts. In all fairness, it must be pointed out that when this programme began it was not known that the southern African population performed regular migrations, nor that individuals which breed in South Africa might, in other years, breed in other regions.

The Nigerian records suggest a rapid decline in *Q. quelea* numbers between 1958 and 1976 (figure 3). However, this has been a period of severe drought in the Sahel and Sudan vegetation

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zones. The total breeding range has diminished and in the remaining area breeding success is exceptionally low in some colonies, and colony failure has been noted (Jones & Ward 1979). It is not yet possible to suggest what effect, if any, the control measures have had on the rate of decline of queleas in Nigeria, or on the size of the reduced population. The test will come when the Lake Chad region again experiences a sequence of good rainfall years and the *Q. quelea* population tends naturally to expand rapidly both in range and density. In my opinion, no feasible control effort will be able to contain this expansion.

In saying that quelea numbers are not, and cannot reasonably be controlled, I do not wish to imply that the efforts of the control units have been wasted. Where the quelea concentrations

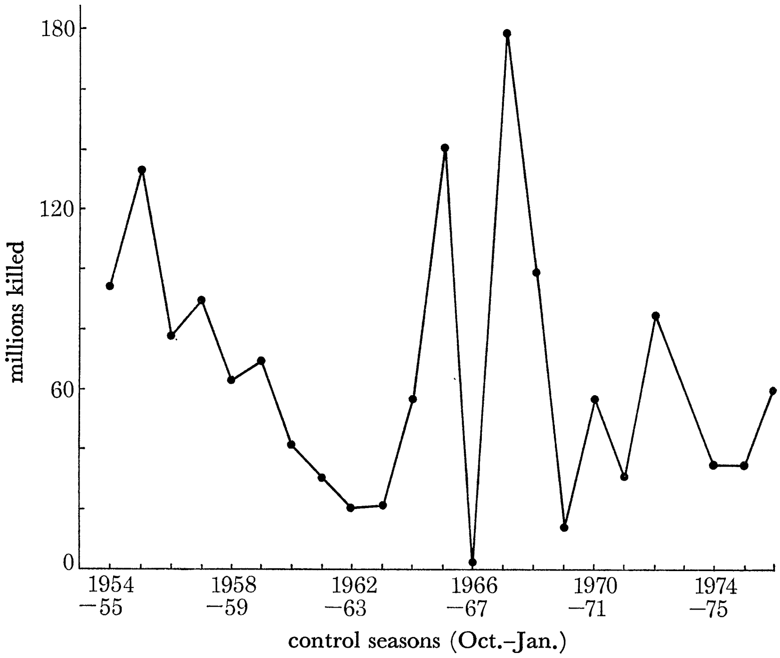

FIGURE 2. Annual changes in the numbers of queleas destroyed in South Africa (data supplied by the South African Department of Technical Services).

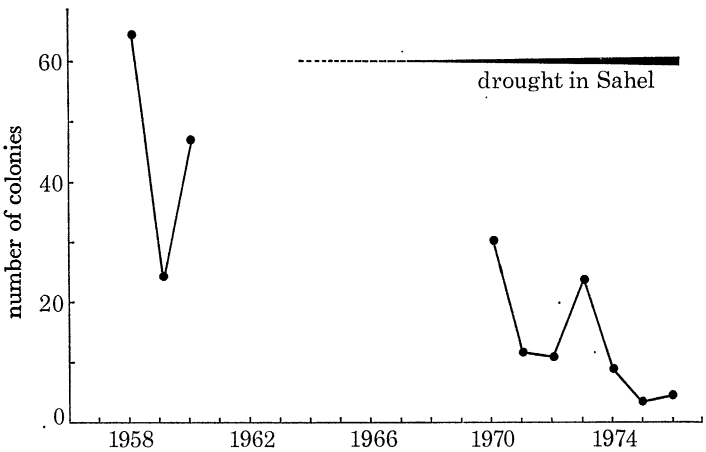

FIGURE 3. Annual changes in the number of breeding colonies located in Nigeria by the Federal Government control unit (data supplied by E. Dorow). Note: no routine surveys were undertaken between 1961 and 1969.

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destroyed have been close to cereal crops at a vulnerable stage of ripeness a measure of crop protection has been achieved. In the examples chosen, Nigeria and South Africa, many of the sites destroyed would be destroyed also in the pursuance of an 'immediate crop-protection strategy' (see below), but in less populous regions of Africa breeding colonies remote from agricultural areas, and roosts formed outside the crop-growing period are being destroyed. Such operations can be justified only within a 'Total Population Control Strategy' and since this is not tenable such operations are deemed to be a costly waste of time and resources.

5. Proposed strategy for quelea control

In a recent review of pest management relating to granivorous birds generally, a case has been made for cautious selection of control strategies with an emphasis on effectiveness (at reducing damage), safety, cheapness and minimal pollution (Dyer & Ward 1979). It is recommended that in any given situation all feasible strategies be ranked according to overall desirability, with the simplest and safest first, and the most complicated and hazardous last. Then, with the aid of a considerable amount of information gained by research, each strategy is considered in turn until one is arrived at which appears practicable.

For most regions of Africa with a serious quelea problem (Senegal River valley, Niger Innudation Zone, Lake Chad basin, central Sudan, southern Somalia and Kenya, central Tanzania, Zambezi valley, Transvaal, and Okavango basin) an 'immediate crop-protection' strategy is advocated. This involves the destruction of only those concentrations (communal roosts or breeding colonies) existing in, or close to, an important cereal producing area, and confined in time to periods of the year when there are crops at a vulnerable stage in the fields. This strategy, more fully described elsewhere (Ward 1972, 1973) does not require repeated surveys of the whole of a population's range, but merely the location and destruction of roosts, or colonies, that are within 'striking distance' of particular crop areas at the time of year the crops are ripening. The tactics employed would vary from region to region depending on facilities, topography, weather, alternative uses for spraying equipment, etc. Thus, helicopter spraying of breeding colonies might be suitable in some areas, whereas in places where the marauding birds are coming from roosts, a ground-based technique (explosives of ground-spraying equipment), or aerial spraying by fixed-wing plane, would be selected.

In a few situations, notably irrigation schemes, alteration of the crop maturation time (by changed agronomic practice or the growing of an earlier or later maturing variety) might be a workable strategy where crops are vulnerable only to birds passing through in the course of their migration (see figure 4).

A great deal of research has been devoted to the development of sophisticated scaring devices and chemical frightening agents, but the results have been very uneven (Park 1974). At first sight the techniques appear to be effective, and unlike the traditional scaring methods used by small farmers, are practicable on large farms where labour costs prohibit scaring by humans. However, there is no proof that queleas are moved from the cereal crops to wild food. In the case of traditional scaring, observation anywhere soon shows that the birds are simply being moved around within the cereal growing areas. There is no reduction in overall crop losses, but there is a more even distribution of the damage. This makes the effort desirable in an area of subsistence farming, but useless in the large cash-crop situation.

There is good evidence that queleas raid crops not because they prefer cereal seeds to those of wild grasses, but because they cannot find the preferred natural food in sufficient quantity (Ward 1965*a*; Bortoli 1974). Thus, to be effective a repellent or scaring device must be capable of dissuading individuals that have no alternative source of food. In experiments designed to test repellents, birds are given a choice of treated and untreated grain. Similarly, fields provided with new scaring devices are compared with others that are without. In such situations the 'protected' cereals may well suffer less than the unprotected plots, for the simple reason that the damage has been deflected to the latter.

It might be argued that even if scaring techniques do little more than make the birds move around constantly, they are useful in reducing damage by restricting feeding time. This is not the case, however, for queleas need to take in food for only a brief period each day; when

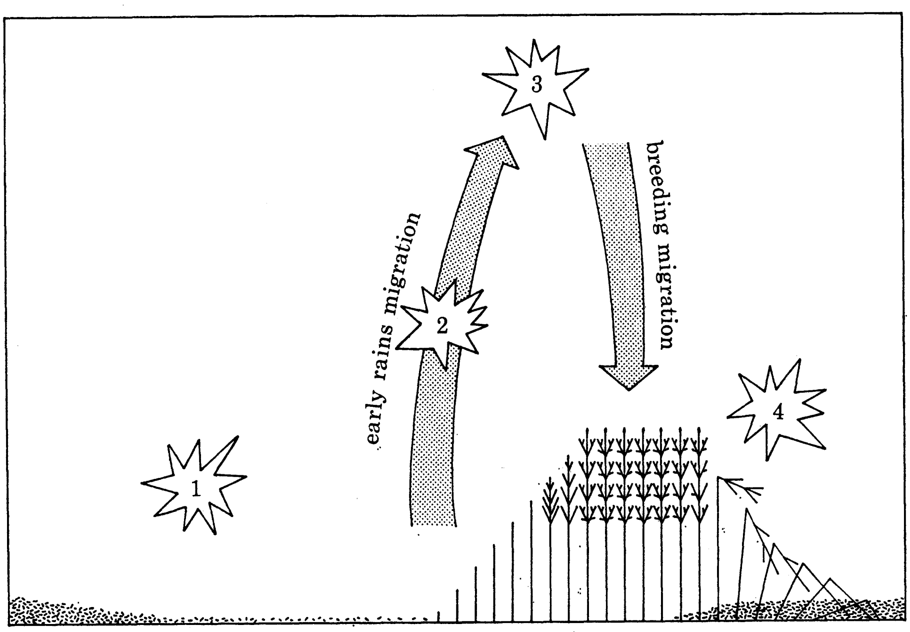

FIGURE 4. The four principal situations in which queleas cause heavy damage, shown in relation to the cycle of availability of their preferred food of wild grass seeds.

SITUATION	APPROPRIATE STRATEGY
1. Cereals grown under irrigation or on receding floods maturing as wild grass seeds are becoming scarce locally	AGRONOMY CHANGE (advanced crop maturation time) IMMEDIATE CROP PROTECTION (by destruction of nearby communal roosts)
2. Cereals maturing early in the wet season and encountered by flocks performing their 'early rains migration'	AGRONOMY CHANGE (advance or retard crop maturation time)
3. Cereals grown in 'early rains quarters' (destination of migrants) and maturing in advance of wild grasses there	AGRONOMY CHANGE (retard crop maturation)
4. Cereals maturing in the late wet season in vicinity of breeding colonies. Although grass seeds are abundant they are temporarily unavailable being covered by dying vegetation. Damage is mostly by newly independent juvenile birds and is very localized	IMMEDIATE CROP PROTECTION (by destruction of breeding colonies close to vulnerable crops)

feeding they rapidly fill a large reservoir (the 'gullet' or 'crop') in the neck, seeds thus stored being digested later when the birds are resting in the roost-site (Ward 1978). Frequent disturbance might well oblige the birds to take longer filling their gullets, but it does not prevent them from doing so.

6. Other migrant granivorous bird pests in Africa

Until recently most of the seed-eating birds that raid cereal crops in Africa have been regarded as sedentary or 'nomadic'. However, a transect study made across the savanna belt of west Africa, from the rain forest to the Sahel, and repeated monthly for 14 months (Ward & Jones 1979) has shown that, like *Q. quelea*, many other species have a regular migration pattern explicable in terms of seasonal rainfall. They include the golden sparrow (*Passer luteus*), village weaver (*Ploceus cucullatus*), red-headed quelea (*Quelea erythrops*), the bishops (*Euplectes hordacea, E. orix, E. afra*), yellow-fronted canary (*Serinus mozambicus*), the doves (*Streptopelia vincacea, S. roseogrisea* and *S. senegalensis*), and glossy starlings (*Lamprocolius* spp.).

Strategies aimed at minimizing damage caused by granivorous birds anywhere in Africa should therefore now be framed in the expectation, if not the knowledge, that the pest species are migratory. It follows, therefore, that in attempting a 'total population reduction strategy' against any of them one cannot consider alone the region where damage is occurring. Rather one must anticipate a programme extending over a vast area and including parts of several States. How large an area would need to be worked out by a comprehensive research programme aimed at delimiting the areas occupied by geographically separate populations, and the extent of the migrations.

The organizations responsible for controlling golden sparrows, village weavers or any other pest species, should carefully consider all alternative strategies, and should sponsor the required research, before embarking on a 'total population reduction strategy' which has little prospect of success.

I wish to thank E. Dorow for supplying unpublished information on quelea control in Nigeria, the Department of Agricultural Technical Services, Pretoria for the data given in figure 2, and Dr J. I. Magor for the biogeographic data shown in figure 1.

References (Ward)

Barré, N. 1974 La pathologie de *Quelea quelea* (L.). *Rapport Inst. Elev. Méd. vét. Pays trop. Maison Alfort.*

Bortoli, L. 1974 Les oiseaux granivores en Afrique tropicale avec référence speciale à *Quelea quelea* – le milieu et les dégâts. *Int. Stud. Sparrows* **7**, 37–75.

Crook, J. H. 1960 Studies on the social behaviour of *Quelea q. quelea* (Linn.) in French West Africa. *Behaviour* **16**, 1–55.

Dyer, M. T. & Ward, P. 1979 Management of pest situations. In *Granivorous birds and ecosystems* (eds S. C. Kendeigh & J. Pinowski). Cambridge University Press.

Gaston, A. 1976 Travaux phyto-écologiques en relation avec la lutte contre *Quelea quelea*. Rapport final, *Inst. Elev. Méd. vét. Pays trop. Maisons Alfort*.

Haylock, J. W. 1959 *Investigations on the habits of Quelea birds and their control.* Nairobi Government Print.

Jones, P. J. 1979 The annual mortality of *Quelea quelea* in South Africa from ringing recoveries during a period of intensive quelea control. *Ostrich.* (In the press.)

Jones, P. J. & Ward, P. 1976 The level of reserve protein as the proximate factor controlling the timing of breeding and clutch-size in the red-billed quelea *Quelea quelea*. *Ibis* **118**, 547–574.

Jones, P. J. & Ward, P. 1979 A physiological basis for breeding failure by red-billed queleas *Quelea quelea*. *J. Zool.* (In the press.)

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Lack, D. 1954 *The natural regulation of animal numbers*. Oxford: Clarendon Press.
Morel, G. 1968 Contribution à la synécologie des oiseaux du Sahel sénégalais. *Mém ORSTOM* **29**.
Morel, G. & Bourlière, F. 1955 Recherches écologiques sur *Quelea quelea quelea* L. de la basse vallée du Sénégal. I. Données quantitatives sur le cycle annuel. *Bull. Inst. fr. Afr. noire* (A) **17**, 617–663.
Morel, G. & Bourlière, F. 1956 Recherches écologiques sur les *Quelea quelea quelea* L. de la basse vallée du Sénégal. II. La reproduction. *Alauda* **24**, 97–122.
Morel, M.-Y. & Morel, G. 1957 Notes complémentaires sur l'écologie el l'éthologie du *Quelea quelea quelea* (L.). *Alauda* **25**, 81–93.
Park, P. O. 1974 Granivorous bird pests in Africa. *Span* **17**, 126–128.
Rowan, M. K. 1964 An analysis of the records of a South African ringing station. *Ostrich* **35**, 160–187.
Roy, J. 1974 Protection des cultures céréalières contre les attaques des oiseaux granivores en savanes sèches africaines. *Int. Stud. Sparrows* **7**, 26–36.
Ward, P. 1964 The war against the quelea bird. *New Scient.* **22**, 736–738.
Ward, P. 1965*a* Feeding ecology of the black-faced dioch *Quelea quelea* in Nigeria. *Ibis* **107**, 173–214.
Ward, P. 1965*b* The breeding biology of the black-faced dioch *Quelea quelea* in Nigeria. *Ibis* **107**, 326–349.
Ward, P. 1965*c* Biological implications of quelea control in West Africa. *C.r. Trav. Congr. Prot. Cult. trop. Marseille* pp. 661–665.
Ward, P. 1966 Distribution, systematics and polymorphism of the African weaver-bird *Quelea quelea*. *Ibis* **108**, 34–40.
Ward, P. 1971 The migration patterns of *Quelea quelea* in Africa. *Ibis* **113**, 275–297.
Ward, P. 1972 New views on controlling quelea. *Span* **15**, 136–137.
Ward, P. 1973 A new strategy for the control of damage by quelea. *Pestic. Abstr.* 97–106.
Ward, P. 1978 The role of the crop among red-billed queleas *Quelea quelea*. *Ibis* **120**, 333–337.
Ward, P. & Jones, P. J. 1977 Pre-migratory fattening in three races of the red-billed quelea, *Quelea quelea*, an intra-tropical migrant. *J. Zool.* **181**, 43–56.
Ward, P. & Jones, P. J. 1979 In preparation.
Ward, P. & Zahavi, A. 1973 The importance of certain assemblanges of birds as 'information-centres' for food finding. *Ibis* **115**, 517–534.
Williams, J. G. 1954 The quelea threat to Africa's grain crops. *E. Afr. agric. J.* **19**, 133–136.

Discussion

N. C. Pant (*Director, Commonwealth Institute of Entomology*, 56 *Queensgate, London SW*7). On the possibility of shifting the cropping pattern in time, so that the crops will not be available to the birds. This is likely to create further problems in regions like tropical Africa – as have been experienced for example with increasing the number of crops per year, and with the new higher-yielding varieties; new pest problems have appeared.

P. Ward. I am sure it will have to be integrated control.

J. Roy (*Locust Control and Emergency Operations, FAO*). This question of population strategy is a very controversial one. We have just seen examples from Nigeria and southern Africa, but in the Senegal valley on the other hand the bird population has been attacked since 1954, with very large-scale campaigns of destruction up to 1968. Since then the bird population has remained very low in this area.

P. Ward. But I don't think it is under control. 1968 was roughly the start of the drought period; and is it not true that the golden sparrow has now replaced *Quelea* as the most important bird pest in that area? The golden sparrow is the equivalent of *Quelea* in the more arid zones to the north. The whole eco-system has shifted further south, bringing with it the golden sparrow. In some areas *Quelea* has simply moved further south. But this is a temporary change, and will be reversed if the rainfall in the Sahel increases again.

E. Dorow (*Gesellschaft für Technischezusammenarbeiten, Postfach* 5180, *Eschborn, West Germany*). I am not sure whether one should follow a population reduction strategy, or an immediate crop protection strategy, but whichever one chooses effective control techniques are required. Also, for population reduction one must be able to reach all parts of a population's range. As long as only a portion of the range is covered, nothing can be achieved.

P. Ward. Where Mr Dorow has been working on *Quelea* control, in northwest Nigeria, there is no doubt that all colonies need to be destroyed. It is a densely populated region, with farms throughout the area occupied by *Quelea*. The danger is in attempting to destroy colonies and roosts in sparsely populated areas. I consider this to be a waste of time and money and an unnecessary spreading around of dangerous chemicals. In such areas I would strongly advocate the destruction only of those colonies or roosts which are close to crops at a vulnerable stage; and then of course the precision of the tactics is extremely important.

Elizabeth Betts (*C.O.P.R., London*). If Quelea are learning to eat maize, should it not be an immediate short-term policy to control all such colonies, before the maize-eating habit spreads across the whole of Africa?

P. Ward. It is not practicable, and in any case other species of birds would learn how to peel maize cobs. I have seen it done by several species of weaver-birds, in many different places, and feel sure it is happening quite independently. It will eventually spread; like the tits learning to open milk bottles in England. Birds are like that.

J. A. Whellan (*C.O.P.R.; London; formerly Government Entomologist, Malawi*). Without belittling the intelligence of birds, I would point out that in southern Africa there are many insects which have become attached to conifers which are not indigenous there, and that potato tuber moths (*Phthorimea*) can find potatoes not only in the field but also in storerooms.

P. Ward. But they haven't learnt to peel the potatoes yet!

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES