

# Status, ecology, behaviour and conservation of Raso Lark *Alauda razae*

PAUL F. DONALD, MARTA DE PONTE, MARIA J. PITTA GROZ and ROY TAYLOR

## Summary

In October 2001, the world population of Raso Lark *Alauda razae*, confined to the uninhabited, arid islet of Raso in the Cape Verde Islands, was estimated at between 128 and 138 birds, of which 61–66% were males. The biased sex ratio was confirmed by standardized observations of randomly selected birds. The male-dominated sex ratio may result from differences in bill morphology and feeding methods. The males spent much time digging for the bulbs of the nutsedge *Cyperus bulbosus*, whereas females were seen to dig far less frequently. These differences may have been due to significant sexual differences in bill size. Both sexes also took a range of invertebrate prey, particularly lepidopteran larvae. Unpaired males showed differences in behaviour to paired males, particularly with respect to song flight length. Measurement of museum skins suggested significant seasonal changes in bill size, possibly related to changes in diet or feeding methods. Bill sizes in both sexes were highly variable, but significantly more variable in males. Nest predation, almost certainly by a near-endemic gecko, was extremely high, Mayfield estimates suggesting a nest survival rate of less than 5% between the onset of laying and the end of incubation. Cats and dogs were thought to be absent, although analysis of droppings shows that both have been present in the recent past. Analysis of historical data shows a strong correlation between population size and rainfall, and numbers of birds have fallen to extremely low levels during droughts. The conservation of the species is discussed in the light of these findings.

## Introduction

Raso Lark *Alauda razae* is confined to the uninhabited 7 km<sup>2</sup> island of Raso (16°37'N, 24°36'W) in the Cape Verde Islands. Discovered as recently as 1897 (Alexander 1898a), the species probably derived from *Alauda*-like stock in the Sahara during wetter glacial intervals (Hazevoet 1995), although its exact taxonomic affinities are unclear. It is possible that the species formerly had a larger range, as the present islands of Raso, Branco, Santa Luzia and São Vicente were joined as a single island during glacial periods of lower sea levels (Hazevoet 1995), and sub-fossil bones found recently on São Vicente may belong to this species. The current distribution may therefore be a relic of its former range (Bourne 1955, den Hartog 1990), although the species may have evolved *in situ* on Raso (Hazevoet 1995). Raso Lark is listed as Critically Endangered by IUCN (BirdLife International 2000) because of its very small distribution and small and fluctuating population. Since 1981, population estimates have ranged between 20 and 250 birds, although the reliability of counts is likely to be highly variable

(Ratcliffe *et al.* 1999). It is probably the least known bird species in the western Palaearctic, due largely to the inaccessibility of Raso and the absence of an ornithological organization in the Cape Verde Islands. Most of what is known derives from the findings of ornithologists visiting the island for short periods, usually to study other species.

Previous authors (e.g. Hazevoet 1995, Ratcliffe *et al.* 1999) have suggested that the population fluctuates in response to rainfall and that long-term desertification is a major threat. This is supported by the observation that birds are largely confined to small areas of green vegetation on the island's flat plain (4 km<sup>2</sup>) and that breeding only seems to take place after rain (a common strategy in African larks), which falls largely in August to October (Alexander 1898b, Hazevoet 1995, Ratcliffe *et al.* 1999). As the Cape Verde Islands lie just outside the Intertropical Convergence Zone (ITCZ), periodic droughts are a feature of the climate of the archipelago (Hazevoet 1995), and Raso Lark has clearly survived droughts lasting at least as long as the documented maximum of 18 years. Being relatively flat (maximum altitude 164 m) and having no permanent water source, water shortage on Raso is particularly severe and so the island has never been inhabited. During the 1968–1980 drought, numbers of Raso Larks may have fallen to less than 20 individuals (Ratcliffe *et al.* 1999). It has been suggested that nest predation may represent a further threat to this species (Castell 1999) and feral cats *Felis catus* have been present on the island in the recent past (Ratcliffe *et al.* 1999). The effects of predation may pose a particularly serious threat to the population when it has already been reduced to low levels by drought, so a critical assessment of all threats is necessary to formulate a conservation strategy for the species. This has hitherto been impossible with the little information available.

This paper describes the results of an expedition to Raso in October 2001. The aims of the research were to assess the species' status, diet, feeding methods and nesting success in order to understand the main threats faced by the species, and to collect documentary data to help clarify the species' taxonomic affinities (Hazevoet 1989) and expand and update standard accounts (e.g. Cramp 1988). A specific aim was to locate and monitor nests to verify the assertion of Castell (1999) that nest predation rates may be high.

## Methods

Visits were made to Raso on 30 September–4 October, 7–12 October, 16 October and 18 October 2001. The island was reached by chartered fishing boat from Tarrafal on the island of São Nicolau, approximately 25 km to the east of Raso. Plant specimens were identified from Lobin (1982, 1986).

### *Counts and assessments of sex ratio*

The whole of the flat plain of Raso (4 km<sup>2</sup>) was covered by four observers walking parallel transects of 50 m length on October 1 and 3. A portable global positioning system (GPS) was used to ensure full coverage and to avoid double counting. The exact location of all birds seen was recorded on the GPS to produce a distribution map. Males and females were distinguished in the counts based on bill size and shape and behaviour. It was not possible to cover the island's

hilly northern side (3 km<sup>2</sup>) with parallel transects, so observers counted the small number of birds present there by visiting all patches of vegetation, following Ratcliffe *et al.* (1999). Initial results suggested an uneven sex ratio, possibly due to under-recording of females. Females may have been less conspicuous because they did not sing or because they may have been incubating eggs. Therefore, a standardized protocol was developed to determine the sex ratio more accurately. The GPS locations of 30 males were selected at random from those of all birds recorded during transects. An observer returned to this location and selected the male nearest to the point as the focal bird. Where no males were immediately obvious, the observer walked a spiral of 10 m intervals away from the point and the first male seen within 25 m of the observer selected as the focal bird. This was done to ensure that singing males were not selected in preference to males closer to the observer that were not singing. The focal bird was then watched for a period of one hour or until it was seen to be paired (in which case the time taken to ascertain this was recorded). The critical period of one hour was derived from observations of incubating females which showed that a male with an incubating female would encounter the female more than three times per hour and spend long periods with her (see Results). Therefore, a male observed for one hour without encountering a female could be safely assumed unpaired. The duration of song flights was also recorded to assess differences in territorial behaviour that could also indicate a male's status.

#### *Feeding and diet*

Observations were made of foraging behaviour of male and female birds to test previous assertions that the sexes feed in different ways. The focal bird was sexed on body size, bill size and shape, and behaviour (particularly song and crest-raising), and a maximum of 10 foraging actions recorded for each bird. A foraging action was defined as a successful attempt to gather food. These were recorded under one of four categories: digging, gleaning from vegetation, gleaning from the ground and turning over stones. Significant differences in feeding methods between males and females were assessed using contingency table analysis. Where possible, the food item was identified. Faecal samples were also collected from the song posts of a number of males, stored dry and analysed under a microscope to identify the main dietary components from undigested body parts.

In order to determine whether any differences in feeding methods could be related to bill structure, an analysis was carried out to determine correlates of bill size. Bill measurements were taken from 45 museum skins (24 in the British Museum of Natural History, Tring, eight in the American Museum of Natural History, New York, five in the Muséum National d'Histoire Naturelle, Paris and eight in the Centro de Zoologia, Instituto de Investigação Científica Tropical, Lisbon). Bill measurements taken were maximum depth and breadth, the length of the upper mandible from feathering on the forehead to bill tip and distance from the notch in the lower mandible to bill tip. Maximum bill length was modelled with general linear models (GLMs) in terms of sex, year of collection and month of collection (the last two to assess long-term or seasonal changes in bill size). As different observers measured skins in different museums, museum col-

lection was added as a factorial variable. Maximal models were simplified by backwards deletion, the minimum adequate model being that in which all, and only, those terms explaining significant independent variation were retained.

#### *Nesting success*

Nests were found by observations of birds carrying nesting material and by the behaviour of females, which exhibited a characteristic furtive behaviour when approaching the nest. The position of nests was recorded using a GPS and nests revisited at intervals of one or two days to monitor progress. Estimates of nest survival rates were calculated using a derivation of the Mayfield method (Mayfield 1975) in which a binary nest outcome variable (failure or no failure) was modelled in the statistical package GLIM assuming binomial errors and a logistic link function, with the number of exposure days being entered as a binomial denominator (Crawley 1993). Subtraction from unity of the back-transformed parameter estimate provided an estimate of the daily likelihood of success. When raised to the power of 15 (assuming three days for laying and 12 days of incubation), this provided an estimate of the likelihood of a nest surviving the entire laying and incubation period.

#### *Behaviour*

Behaviour of both the males and females during incubation was of interest for several reasons. It is poorly documented, standard accounts (e.g. Cramp 1988) being incomplete and based largely on casual observations. Behaviour might also indicate the species' taxonomic affinities (Hall 1963, Hazevoet 1989). Furthermore, during the assessment of sex ratio it was important to assess how long a male with an incubating female nearby would have to be watched before his status as a paired male could be ascertained (see above).

Eight one hour watches of different nests were made from a distance of 50 m or more and the movements of females on and off the nest recorded. The number of times that the male and the female were recorded together near the nest was also recorded. The duration of song flights was recorded opportunistically to document this phenomenon and to assess whether a male's status (paired or unpaired) could be determined by song flight duration and thereby provide additional support to the standardized watches of males described above. Differences in incubating and non-incubating behaviour of females with nests, and in song lengths of paired and single males, were tested using Mann–Whitney *U*-tests.

#### *Predator status*

The presence of cats on the island was assessed by walking transects at night and periodically shining a powerful torch beam in a 360° arc to try to detect reflections from eyes. In addition, sand traps were baited with fish and tracks of animals attracted to the bait examined. A large number of mammalian faeces were located in one area in the north-east of the island and were collected for examination. Counts of avian predators or potential predators on the island were

also undertaken. Rat *Rattus* traps were taken to the island but were not used for fear of catching the near-endemic giant gecko *Tarentola gigas*.

#### *Population and rainfall*

In order to assess quantitatively the assertion of Hazevoet (1995) and Ratcliffe *et al.* (1999) that Raso Lark populations fluctuate in response to drought, rainfall data from a recording station at Tarrafal, São Nicolau (16°34'N, 24°22'W), around 25 km east of Raso and the nearest station to the islet, were extracted. These were correlated with the counts of Raso Larks made since 1968 as presented by Ratcliffe *et al.* (1999). The population in each year was plotted against the rainfall in the previous year, since it is likely that populations are determined by productivity in the previous breeding season. Non-parametric correlation was used to assess the significance of the relationship.

## **Results**

#### *Counts and assessments of sex ratio*

Transect counts recorded 128 birds, the great majority (95%) of which were recorded on the flat plain that makes up over half the island's total area. Only six males and one female were recorded above the 50 m contour in the northern hills (Figure 1). Birds were widely scattered across the plain, but were more numerous around the edges of the plain and along dry riverbeds and absent from large unvegetated parts of the interior (Figure 1). Of the 128 birds recorded, 85 (66.4%) were males, a ratio of two males to one female. The standardized watch of 30 randomly selected males recorded a ratio of 19 paired to 11 unpaired males. If this ratio is applied to the count of 85 males made during transects, the predicted number of females was 53, a ratio of 1.6 males per female. The mean period of observation of paired males needed to detect the presence of the female was 188 seconds, compared with the hour of observation of unpaired males with no female being seen. Differences in song length of birds recorded as paired or unpaired and the frequent meetings of males and females during the incubation period (see below) added confidence to the classification of males as being paired or unpaired. No unpaired females were seen.

#### *Feeding and diet*

There were significant differences between the sexes in feeding methods (Figure 2), with males digging more than females and females turning over stones more than males. Males were seen to dig holes up to 6 cm deep with their bills, and in some places the ground was covered with holes, previously mistaken for collapsed petrel (*Hydrobatidae*) burrows (den Hartog 1990). Holes were dug almost exclusively around the base of the nutsedge *Cyperus bulbosus* (and possibly other *Cyperus* species), and males were seen to take the bulb of that plant, a food item not seen to be taken by females, which dug shallower holes from which they were seen to take mainly insect larvae. Several food items were taken by both sexes, including insect larvae, adult Lepidoptera and Orthoptera, grass seeds and

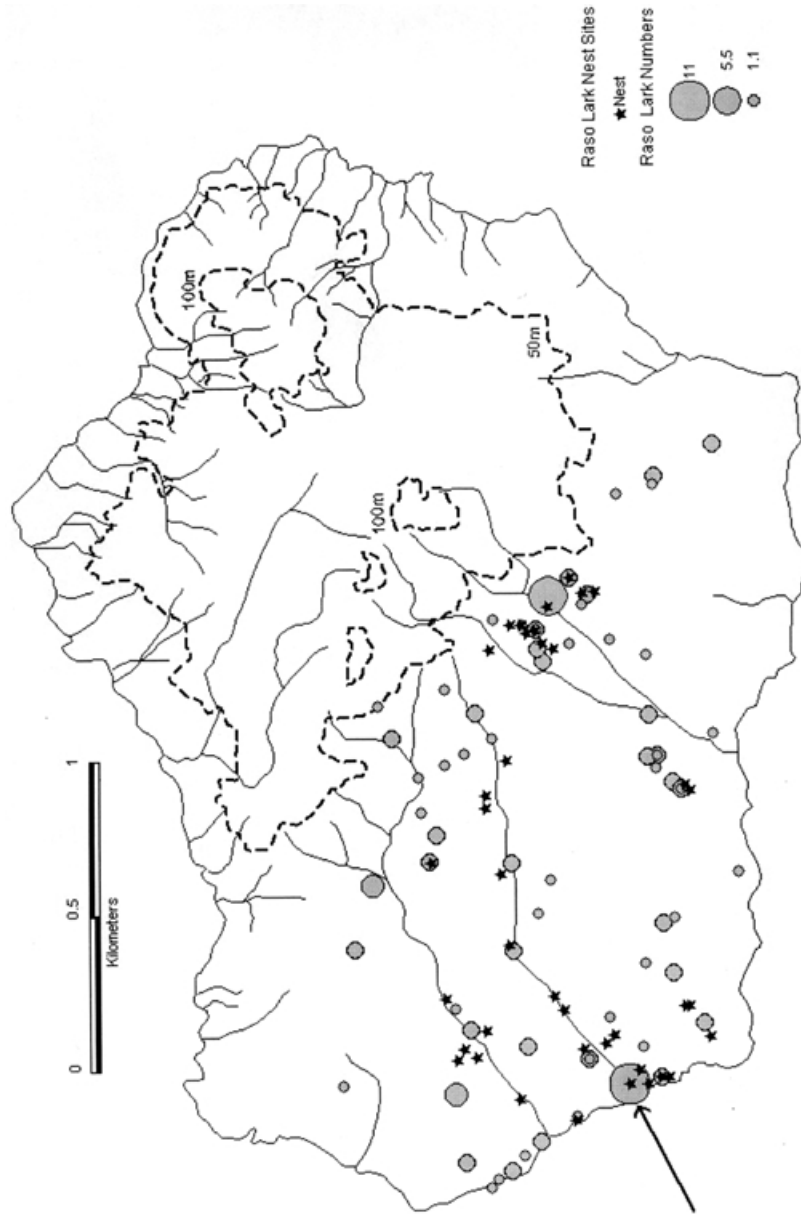


Figure 1. Distribution of Raso Larks on Raso, October 1991. Solid lines mark dry stream beds (ribeiras); dotted lines mark the 50 m and 100 m contours. The positions of the 40 nests found are marked with stars. The locations of six males and one female found above the 50 m contour were not recorded in the field and are omitted from the map. The main landing site is marked with an arrow.

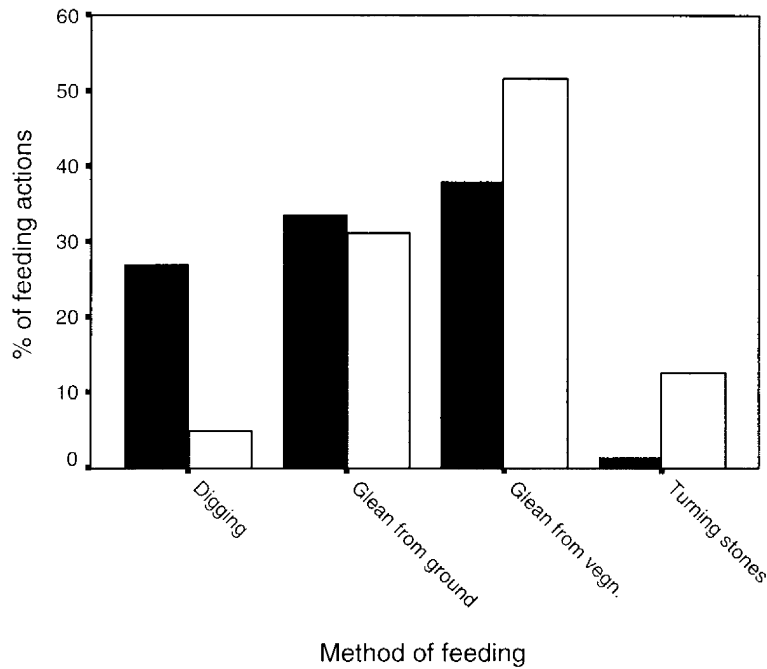


Figure 2. Feeding methods used by male (filled bars,  $n = 137$ ) and female (open bars,  $n = 103$ ) Raso Larks. There was a significant difference between the sexes in the frequency of different feeding methods ( $\chi^2 = 26.1$ ,  $df = 3$ ,  $P < 0.001$ ).

leaves. Both sexes were also seen to break off and chew branches of *Zygophyllum simplex*, probably to extract water. On one occasion, birds were seen unsuccessfully chasing small skinks *Mabuya stangeri*. Analysis of 75 faecal samples collected from the song posts of a number of males suggested that lepidopteran larvae comprised the majority of insect larvae taken and that a number of other prey items were taken (Table 1). Plant material was present in all the faecal samples examined and 21% of faecal samples contained only vegetable material.

Table 1. Frequency of occurrence of different food items in 75 faecal samples collected from males' song perches.

| Item                            | % faecal samples ( $n = 75$ ) |
|---------------------------------|-------------------------------|
| Vegetable material <sup>a</sup> | 100                           |
| Lepidoptera larvae              | 47                            |
| Seed testa                      | 31                            |
| Adult coleoptera                | 15                            |
| Gastropods                      | 11                            |
| Diptera                         | 4                             |
| Coleoptera larvae               | 4                             |
| Araneae                         | 3                             |
| Formicidae                      | 3                             |

<sup>a</sup> 21% of samples contained *only* vegetable material.



Table 2. Measurements (mm, mean  $\pm$  1 SE) of bills of Raso Lark.

| Measurement    | Male ( $n = 26$ ) | Female ( $n = 19$ ) |
|----------------|-------------------|---------------------|
| Upper mandible | 14.4 (0.18)       | 11.7 (0.11)         |
| Max. Depth     | 5.9 (0.05)        | 5.2 (0.09)          |
| Max. Width     | 5.7 (0.08)        | 5.0 (0.10)          |

Measurements of males were significantly larger in all cases (ANOVA,  $150.0 > F_{1,43} > 25.0$ ,  $P < 0.001$ ).

### Bill measurements

There were significant differences between the sexes in all bill measurements (Table 2), the bills of males averaging 23.1% longer than those of females. When crudely calculated as length  $\times$  maximum depth  $\times$  maximum width, bill volume was around 60% greater in males. The minimum adequate model also retained month of collection in addition to sex, fitted values suggesting an increase in bill length from January to October (Table 3), although whether this was due to changes in the bill length of individual birds or to differential mortality of birds of different bill lengths is uncertain. Year of collection and museum (and hence the identity of the measurer) did not significantly influence the measured bill length.

Bill length was highly variable in both sexes (the range representing 17.1% of the mean in females and 27.7% of the mean in males) but in males was significantly more variable than in females (Bartlett's test,  $P < 0.02$ ).

### Nesting and nest success

A total of 40 nests was found, excluding those obviously old or abandoned. Our visit to Raso clearly coincided with the very start of the breeding season, as most of the first nests were found during nest building and no chicks were seen. No chicks were observed during the study so results refer only to the period of laying and incubation. All but one of the nests were built under the low halophyte *Zygophyllum simplex*, the exception being placed under a clump of the grass *Aristida cardosoi*. *Abutilon pannosum*, the plant under which Castell (1999) found all his nests, was present on the island but not used for nesting. The incubation period could not be determined with certainty as no chicks were seen, but one nest (of three eggs) was incubated for at least 13 days and another for at least 12 days, suggesting that incubation may be longer than the 11 days of Skylarks *Alauda arvensis* (Donald 1999). Clutch sizes were known with certainty from 21 nests and ranged from one to three (Figure 3).

The daily nest survival rate was estimated from the 27 nests yielding data

Table 3. Minimum adequate model of bill length.

| Variable   | $F_{1,42}$ | $P$        |
|------------|------------|------------|
| Sex        | 158.6      | $< 0.0001$ |
| Month      | 4.6        | $< 0.05$   |
| Year       | —          | NS         |
| Collection | —          | NS         |

This bivariate model explained 82% of the variation in bill length. The regression coefficient of "month" (measured as 1 = January, 12 = December) was positive.



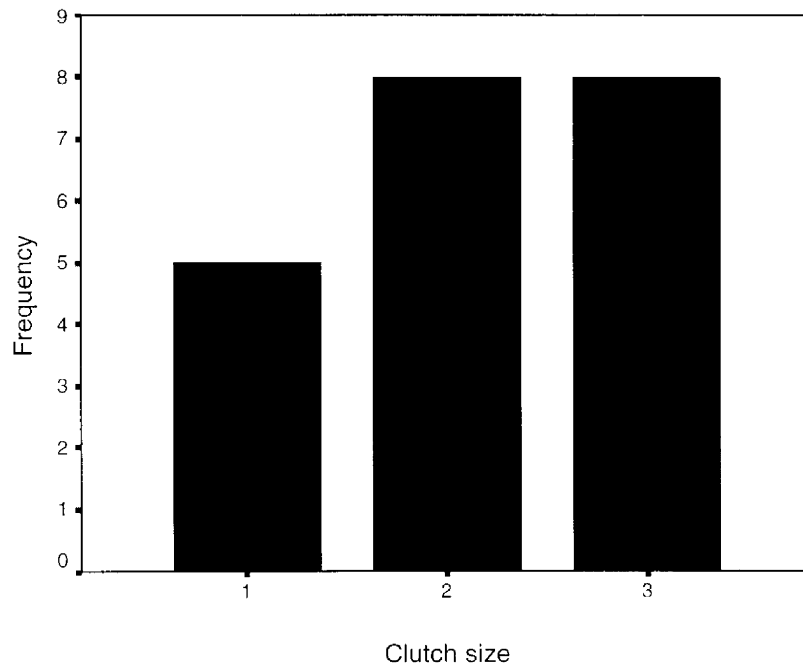


Figure 3. Distribution of clutch sizes in 21 Raso Lark nests, 1 October to 16 October 2001.

suitable for Mayfield analysis to be 81.6%, equating to an overall survival rate of just 4.7% over the assumed 15-day laying and incubation period. All nest failures were due to predation, at least some of which took place at night. In each case, large or small eggshell fragments were left in the nest and the nest lining was generally undisturbed.

*Predator status*

Of the seven potential nest predators on Raso in October 2001, only the Cape Verde giant gecko, endemic to Raso and the neighbouring island of Branco, was common (Table 4). This species is thought to feed on broken seabird eggs and a

Table 4. Status of potential nest predators of nests of Raso Lark, October 2001.

| Predator   | Status on Raso |
|--|----------------|
| <b>Birds</b>   | 2 pairs        |
| Neglected Kestrel <i>Falco (tinnunculus) neglectus</i> |                |
| Brown-necked Raven <i>Corvus ruficollis</i>            | 1 or 2 pairs   |
| Cape Verde Barn Owl <i>Tyto (alba) detorta</i>         | Present?       |
| <b>Reptiles</b>  |                |
| Cape Verde Giant Gecko <i>Tarentola gigas</i>          | Common         |
| <b>Mammals</b>   |                |
| Cat <i>Felis catus</i>                                 | Absent         |
| Dog <i>Canis familiaris</i>                            | Absent         |
| Rat <i>Rattus</i> spp.                                 | Absent         |

wide range of other foods, possibly including seabird chicks (den Hartog 1990, Hazevoet 1995) and is certainly large enough to predate a lark nest. The two other geckoes thought to be present on Raso (*Tarentola caboverdiana razoensis* and *Hemidactylus bouvieri razoensis*) are less common than *T. gigas* and far smaller. There was no evidence of cats on the island; none were encountered during sand trapping or night transects and no fresh droppings were seen. Nor was there evidence of rats on the island; the abundant food left on the island by visiting fishermen was untouched. Of the potential avian predators, only Brown-necked Raven *Corvus ruficollis* was likely to predate eggs. However, only one or two pairs were present, and predated nests did not show the disturbed nest lining usually associated with corvid predation. It seems likely, therefore, that the principal or sole predator of Raso Lark eggs was the giant gecko, although this needs confirmation.

Analysis of the mammalian faeces found on Raso suggested they were old. At least some of the mammalian faeces examined were canine in origin, probably from a single dog known to have been present on the island in the late 1990s, which was eventually shot.

#### *Population and rainfall*

During the drought of 1968 to 1980, the population fell to 15 pairs but recovered quickly after the end of the drought (Figure 4a). Population size was positively correlated with the rainfall in the previous year; more pairs were present following years of higher rainfall (Figure 4b).

#### *Behaviour*

A high degree of mate guarding was apparent, particularly during nest building. Unpaired males often entered the territories of paired birds from which they were aggressively chased off. Paired males always won territorial fights, which closely resembled those of Skylarks. Unpaired males defended territories of around the same size as paired males but defended them less vigorously, often tolerating other unpaired males in close proximity. One unpaired male that was closely followed for several hours was found to simultaneously defend two territories around 500 m apart. During territorial conflicts, males adopted an aggressive stance similar to that of Skylark, in which the body was angled forwards and downwards, the crown and back feathers were raised and the tail was spread and held down.

The courtship display of the male closely resembled that of Skylark. The male approached the female, often singing quietly, and performed a series of vertical hops with the crest raised and often with the wings held open. The female solicited copulation by a display in which the head was held low and the wings shivered.

Nest building behaviour and the nest itself resembled closely that of Skylark. Only the female built, but the male remained in close attendance. As with Skylark, periods of nest building, when the female took material to the nest every minute or so, were interspersed by long gaps during which the pair fed nearby without visiting the nest. Pairs flew up to 200 m to collect nesting material, which

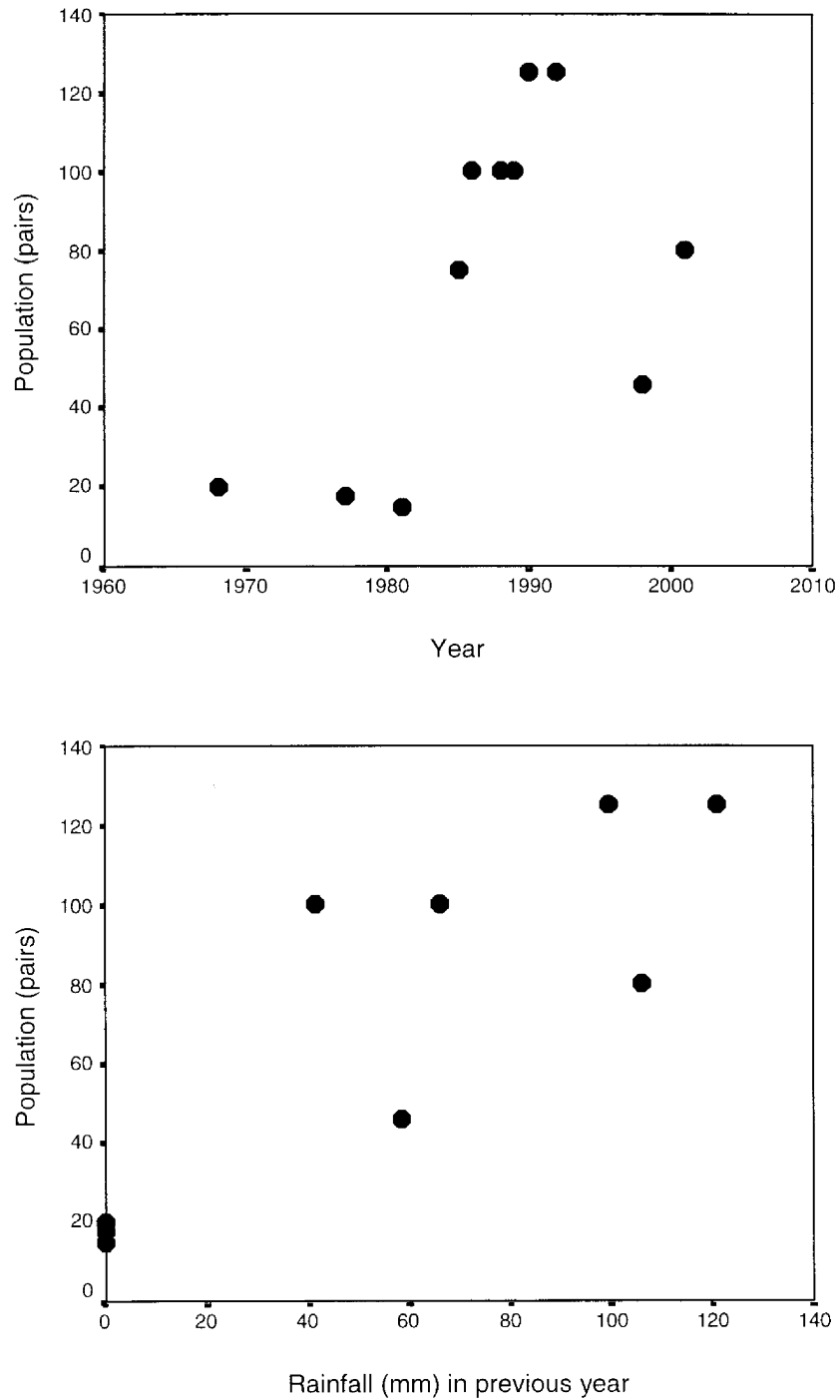


Figure 4. (a) Population trends of Raso Lark, 1968 to 2001. Data updated from Ratcliffe *et al.* (1999). (b) Relationship between population estimates of Raso Lark and rainfall in Tarrafal, São Nicolau, the previous year. The two were significantly correlated ( $r_s = 0.824$ ,  $n = 9$ ,  $P < 0.005$ ).

was mainly dead grass, although fresh vegetation was also used on occasion. In one case, nesting material was collected from a recently predated nest of the same pair nearby. The nest consisted of a scrape around 3 cm deep dug by the female and lined with dead grass. The sides of the scrape were lined before the bottom. Several scrapes could be dug before one was selected for lining. As with Skylarks, predated nests were rapidly replaced.

Incubation was undertaken by the female alone, contrary to observations from the 1890s that both sexes are involved (Cramp 1988). Feeding of the incubating female by the male was observed at least six times, suggesting that this behaviour is far more frequent in this species than in Skylark, in which it is extremely rare (Donald 1999). When approached by observers, females either left the nest with a poorly developed distraction display (far less developed than in Skylark) or remained on the nest. Incubating females spent longer off the nest than on it, with incubation periods averaging 9.4 min and feeding and preening breaks averaged 13.1 min, though the difference was not statistically significant (Mann–Whitney  $U_{12,12} = 71.5$ , ns). During these breaks, the male tended to keep close to the female but did not mate guard as closely as during nest building. Unlike Skylark, eggs were sometimes laid more than one day apart and incubation sometimes started before the last egg was laid. There could be a gap of up to three days between completion of the nest and the onset of laying.

Two types of song were heard, the first a disyllabic *chirrup* as described by Alexander (1898b) and Hazevoet (1989). The other was a far more complex and musical Skylark-like song given primarily during ascent and descent in song flights. This was less mimetic than that of Skylark but on one occasion included an imitation of Whimbrel *Numenius phaeopus* (a species present on the island at the time). The mean recorded song flight lasted 139.1 seconds (median 64 seconds, range 6–872 seconds,  $n = 75$ ) (Figure 5). Birds always faced into the prevailing northerly or north-easterly wind, and song flight activity was greatly reduced on days with higher wind speeds. If wind speeds increased during a song flight, males rapidly descended. The duration of song flights and the heights reached by singing birds appeared to experienced observers to be similar to those of Skylark. Much of the variation in song flight lengths could be explained by the status of the male, with unpaired males having song flights averaging five times longer than paired males (Figure 5).

## Discussion

The population of Raso Larks in October 2001 was between 39% and 51% higher than that recorded during the previous systematic count in 1998 (Ratcliffe *et al.* 1999). Furthermore, that count was conducted in February, after the main breeding season when populations should be at their highest, so a real increase in the population seems to have occurred. However, the discovery of a heavily biased sex ratio suggests that at least some previous counts could have overestimated the size of the reproductive population by including unpaired males. It is possible that some of the very low counts recorded during the drought of 1968 to 1980 (Figure 4a) similarly overestimated the population, and if the biased sex ratio apparent in 2001 is a general feature of the species' demography, the number of females probably fell to single figures. Furthermore, given the non-

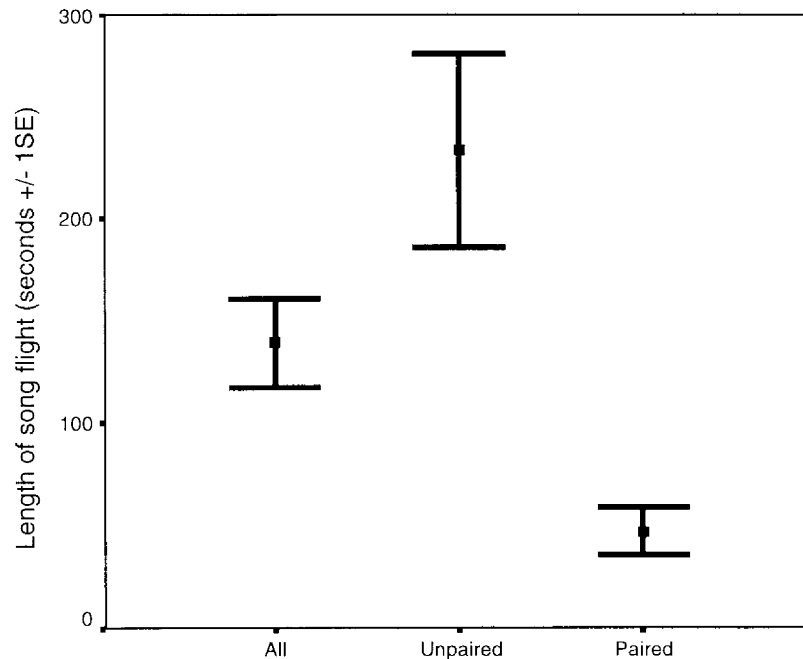


Figure 5. Duration of aerial song flight by all birds combined ( $n = 75$ ) and by males known to be unpaired and paired separately. There was a highly significant difference in duration of song flights of paired and unpaired males (Mann-Whitney  $U_{19,23} = 71.5$ ,  $P < 0.001$ ).

random distribution of lifetime reproductive output among individuals, the effective breeding size must have been considerably lower (Grant and Grant 2000). Longer droughts than the most recent in 1968–1980 have been recorded, and the species must have come close to extinction many times. Low populations in drought may result from increased mortality, reduced productivity or both, as is the case with Darwin's finches on the climatically similar Galapagos Islands (Grant *et al.* 2000). Although the effects of accelerated global climate change on rainfall patterns in Cape Verde cannot presently be assessed, it is clear that increasing drought would pose a severe threat to the survival of this species. Alternatively, the 20–30% increase in rainfall in tropical oceans suggested by several models of climate change (e.g. Whetton *et al.* 1996) might benefit the species.

The reasons for the biased sex ratio could not be determined from the data collected. However the empirical differences in bill structure (Table 2; see also Burton 1971) and, probably as a consequence, in feeding methods support the assertion of Hazevoet (1995) that “to a certain extent the sexes behave like separate ecological species”. The most obvious difference in the sexes' feeding behaviour was the digging of holes by males to uncover the bulbs of *Cyperus bulbosus*. These are of sufficiently high food value to humans that they can profitably be harvested during periods of food shortage. Although small (around 10 mm by 5 mm in the plants examined on Raso), the bulb yields 82.46 g of carbohydrate and 11.6 g of water per 100 g of tissue. During the dry season, and particularly

during droughts, this may be a source of food and water that is available only to males. Drought may therefore contribute to lower female survival rates and could account for the biased sex ratio. Very similar effects of drought on sex ratios have been documented in Darwin's finches in the Galapagos (Grant and Grant 1992).

The very low nesting success of Raso Larks confirmed earlier suspicions that nest predation is high (Castell 1999). Despite the absence of terrestrial mammals and the paucity of avian predators, nest success rate, at least at the start of the breeding season, is only around one fifth of that of Skylarks nesting in predator-rich farmland in southern England (Donald 1999). Nest predation is almost certainly mainly by the near-endemic Cape Verde giant gecko, a species that has been present on Raso much longer than Raso Lark (Carranza *et al.* 2000). It therefore appears likely that Raso Larks are able to survive the high rates of nest predation observed. Further data are needed to determine whether the high rates of predation observed are constant throughout the breeding season and whether predation rates differ after hatching.

Many aspects of the species' ecology and behaviour closely resemble that of Skylark, suggesting that the species' current placing in the genus *Alauda* is correct. A similar conclusion was reached by Hazevoet (1989), based on song and song flights.

#### *Conservation*

Raso Lark has been protected specifically under Cape Verde law since 1955, and Raso was declared a National Park in 1990. Government permission is needed to land on Raso, though this is rarely sought. Unregulated visiting could result in the introduction of predators such as cats and dogs, which have both been present in the past, and could increase the risks of nest loss to trampling or disturbance, particularly in the high density population found around the main landing site (Figure 1). However, legal protection alone is unlikely to be sufficient to protect this species in the long term. The possibility of increased desertification through global climate change is likely to pose a particularly severe threat to the species that legal protection will be unable to mitigate. Although it is not known to have ever occurred on any other islands, it is likely Raso Lark had a wider range at the height of the Ice Age around 18,000 years BP, when low sea levels connected Raso with the present islands of Branco, São Vicente and Santa Luzia (Hazevoet 1995). The establishment of a second population on a larger island would reduce the risks of extinction through extreme events. If the species can be shown to have been present on Santa Luzia (35 km<sup>2</sup>), for example through the discovery of sub-fossil bones, the possibility of re-establishing a new population on that island could be considered. Although previously inhabited and heavily grazed, Santa Luzia is now uninhabited and may be appropriate for a reintroduction project if conditions are suitable. The suitability of Santa Luzia for translocation needs to be assessed, and the presence of important plant species such as *Cyperus bulbosus* and *Zygophyllum simplex* established. Cape Verde giant gecko is not present on Santa Luzia, so nest productivity might be increased, although the status of other potential predators would need to be established.

The species requires more frequent monitoring than has been achieved to date

and all ornithologists visiting Raso are encouraged to undertake a systematic count. The presence of goats, cats and rats also needs to be assessed on a regular basis. The species requires considerable further research. In particular, it is important to determine the reasons for the uneven sex ratio, since a reduced population of females represents a severe threat to the species' continued survival.

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PAUL F. DONALD

Royal Society for the Protection of Birds (RSPB), The Lodge, Sandy, Bedfordshire SG19 2DL, U.K.

MARTA DE PONTE

Sociedad Española de Ornitología (SEO), Avda Trinidad 55, Edificio Anchieta, Pta 121, 38206 La Laguna, Tenerife, Spain.

MARIA J. PITTA GROZ

Sociedade Portuguesa para o Estudo das Aves (SPEA), Rua da Vitoria, 53–3 Esq., PT-1100-618 Lisboa, Portugal.

ROY TAYLOR

Royal Society for the Protection of Birds (RSPB), Westleigh Mews, Wakefield Road, Denby Dale, Huddersfield, West Yorkshire HD8 8QD, U.K.

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