RESEARCH DISCUSSION PAPER
Number 14
March 1997

Endemic Birds of Namibia:

Evaluating their status and mapping biodiversity hotspots

by

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Acknowledgements

Most of the funding required for this project was provided by the Namibia National Biodiversity Program, Directorate of Environmental Affairs. Smaller grants were also gratefully received from The Carnegie Trust for the Universities of Scotland and the British Ornithologists' Union. The Namibia Nature Foundation provided administrative support, in addition to hiring out a vehicle for field work purposes. Rob Simmons, Phoebe Barnard, Chris Brown (Ministry of Environment) and David Houston (University of Glasgow) offered valuable logistical support, help and advice at various stages of the work. GIS Arc/Info and ArcView software was provided by Mr Shearer and Ms Drummond of the Department of Geography and Topographical Sciences (University of Glasgow).

The following people collected data in 1993, some of which have been used in this study: Dave Ward, Ian Reid, Chris Brown, Francois and Linda Malan, Sakkie van Plato, Dieter Ludwig and Peter Bridgeford.

Digital GIS maps were provided by the Remote Sensing Centre, Windhoek (rainfall, altitude, quarter degree squares, land tenure) and Avian Demography Unit, University of Cape Town (avi-vegetational zones). Updated data from the Southern African Bird Atlas Project were made available by Chris Brown and John Mendelsohn. Jacquie Tarr drew the bird illustrations for the front cover.

This project would not have been possible without the kind permission of all landowners who allowed us to count birds on their land. We are also indebted to Christian Boix for his contagious enthusiasm, and to Linda Baker for her hospitality, friendship and support throughout.

Summary

Line transect sampling was undertaken throughout Namibia between January and July in 1996 and records were made of all sightings of the following endemic bird species: Hartlaub's francolin, Rüppell's korhaan, Rüppell's parrot, violet woodhoopoe, Monteiro's hornbill, Carp's black tit, barecheeked babbler, Herero chat, rockrunner and whitetailed shrike (*Francolinus hartlaubi, Eupodotis rueppellii, Poicephalus rueppellii, Phoeniculus damarensis, Tockus monteiri, Parus carpi, Turdoides gymnogenys, Namibornis herero, Achaetops pycnopygius, Lanioturdus torquatus*). Both riverine and non-river transects were undertaken.

A number of environmental variables were identified and used to group the transects. For each species, density within each unique combination of environmental variables was calculated for the non-river transects using a Fourier series. The number of birds per km of river was calculated for the river transects. The relationship between selected environmental parameters and estimated density was determined using regression analysis for the river and non-river transects. For all species, significant relationships were obtained using a combination of one, two or all three of the following environmental variables: altitude (200 m intervals), vegetation zone (nine zones), rainfall (100 mm intervals).

For each species, the derived regression equations were used to predict bird abundance in each existing combination of environmental variables. Using GIS mapping, these predicted values were used to calculate estimates of total population size and to define the limits of each species' distribution. Nine of the species share similar distribution limits, while the distribution of the tenth species (Rüppell's korhaan) overlaps substantially with these. The following total population estimates were made: Hartlaub's francolin 26 527 ± 3 753; Rüppell's korhaan 99 860 ± 23 615; Rüppell's parrot 29 466 ± 16 392; violet woodhoopoe 1 848 ± 394; Monteiro's hornbill 339 565 ± 34 491; Carp's black tit 493 550 ± 83 970; barecheeked babbler 79 065 ± 25 898; Herero chat 108 104 ± 3 606; rockrunner 96 464 ± 46 968; whitetailed shrike 1 501 029 ± 187 270.

Estimates were made of population sizes for each species within different land use categories e.g. National Parks, commercial and communal farming areas. The status of each species is discussed, and the adequacy of the existing protected areas for protecting these populations, is assessed. For many of the species the existing Parks may not support viable populations.

An index of diversity (the Shannon index) was calculated, based on the predicted abundance of the species within quarter degree squares, and used to determine the locations of 'hotspots of endemism'. The majority of the hotspots fall within a relatively small area of the Escarpment avi-vegetational zone. Very little of this zone falls within protected areas and we suggest that the designation of a new conservation area within this zone could significantly enhance the protection status of the endemic birds.

A method for the future monitoring of some of the species is suggested, based on the relationship between predicted bird abundance and reporting rates provided by the Southern African Bird Atlas Project. A number of limitations to this approach for estimating total population size are identified. However, it could legitimately be used for predicting changes in bird numbers within selected quarter degree squares, and to monitor changes in species distributions and abundances. The effect of factors such as land use or habitat deterioration on these species could then be evaluated. Further monitoring techniques are suggested for the remaining species.

Chapter 1: Introduction

Biodiversity and endemism in Namibian birds

Biodiversity can be defined as 'the totality of genes, species and ecosystems in a region' (WRI *et al* 1992). The need actively to maintain maximum biological diversity (biodiversity) has been increasingly recognised over the last few decades, particularly as rates of environmental change and degradation increase (IUCN *et al* 1980). Southern Africa contains approximately 7% of the world's avian species, of which around 8% (74 species) are endemic to the region (Ginn *et al* 1989). Approximately two-thirds of the southern African endemics have evolved in association with the arid conditions in the South-Western Arid zone, which includes most of Namibia (Clancey 1986). Over 150 species of birds are currently classed as endangered, vulnerable, rare or amber in the Namibian Red Data Book (CJ Brown, pers. comm.).

Bibby *et al* (1992) identified priority areas for biodiversity conservation on a global scale based on concentrations of restricted-range bird species. In their study, species with known ranges of less than 50 000 km^2 were defined as restricted-range species resulting in the inclusion of 27 % of all bird species world-wide. Areas containing two or more of these species were defined as 'endemic bird areas', of which there were 221, including 95% of the restricted-range species. Using these criteria, none of the bird species in Namibia is classed as 'restricted-range' (as they are assumed to occur over a greater range than 50 000 km^2) and, although four endemic bird areas are identified in southern Africa, no part of Namibia is classed as such. However, at a national, rather than global, scale, a species can be defined as 'endemic' to a region if 95 % or more of its known population range is within that region, whilst those with 90 % or more of the known population range within a region can be considered 'near-endemic'.

Approximately 13 species of birds are regarded as endemic, or near-endemic, to Namibia and most of these have distributions restricted to the north-west of the country (Maclean 1993; Newman 1993). Although many of these species may extend into neighbouring countries, the extent to which they do so is not well known. These species are all classified as 'amber species' in the Namibian Red Data Book, indicating that regular monitoring is desirable, because of low numbers, restricted distributions, specialised requirements or poorly known status. It is illegal to hunt, kill, trap or trade in these species without a permit from the government. Three of the 13 species have distributions restricted to the western coastal strip and escarpment fringe and have previously been studied to some extent. These include the dune lark (*Mirafra erythrochlamys*), Gray's lark (*Ammomanes grayi*) and the Damara tern (*Sterna balaenarum*). These species, with distributions discrete from the other 10 endemics, were not included in this study. The species included here are:

1) Hartlaub's francolin *Francolinus hartlaubi*
2) Rüppell's korhaan *Eupodotis rueppellii*
3) Rüppell's parrot *Poicephalus rueppellii*
4) Violet woodhoopoe *Phoeniculus damarensis*
5) Monteiro's hornbill *Tockus monteiri*
6) Carp's black tit *Parus carpi*
7) Barecheeked babbler *Turdoides gymnogenys*

8) Herero chat *Namibornis herero*
9) Rockrunner *Achaetops pycnopygius*
10) Whitetailed shrike *Lanioturdus torquatus*

Table 1 gives some general information on the ecology of these species.

There are a number of potential threats to the populations of Namibian endemics. Namibia is sub-Saharan Africa's most arid and agriculturally marginal nation. Degradation of the environment, such as desertification and bush encroachment, occurs as a consequence of periodic drought, population growth and poor land management (Seely 1991). Although human population density is relatively low (at 1.7 people per km^2), annual population growth rate is estimated at over 3% (Davies 1993) and is already putting extreme pressure on the arid landscape and its resources. Pressure on the environment resulting from eco-tourism is also expected to increase significantly in the near future. The exploitation of some endemic bird species, for example, for the cage bird trade may be ecologically viable but may result in significantly depleted populations if not properly monitored and regulated. Current levels of illegal trading in Rüppell's parrots originating in the wild are unknown. Adequate assessment and monitoring of population size and structure is crucial if legal trade in wild Rüppell's parrot (adults, chicks or eggs) is to be sustainable. Similarly, proposed hunting of Rüppell's korhaan on private game reserves must be based on sound knowledge of population size and recruitment rate.

In addition to constitutional commitments to the maintenance of ecosystems, essential ecological processes and biological diversity, Namibia has international environmental responsibilities and commitments as a signatory to the Convention on Biological Diversity (which emanated from the United Nations Conference on Environment and Development held in Rio de Janeiro, 1992). Currently over 13% of the land area of Namibia falls within state-owned Parks and Recreation Areas. However, many of these areas have been designated and managed for politically motivated reasons and may not always coincide with areas rich in biodiversity (Robertson *et al* 1995). In order adequately to protect Namibia's unique avifauna, reliable information is required on the distribution, requirements and current status of the species.

How well are Namibia's endemic birds known?

The Southern African Bird Atlas Project (SABAP)

The recently completed Southern African Bird Atlas Project (SABAP) is a comprehensive database which provides baseline information on the distributions and ranges of all bird species within southern Africa (Harrison 1987). This project was carried out over many years by both amateur and professional birders and utilised a record-card system to record the presence of all bird species across the subcontinent. Data were recorded at resolutions of quarter-degree grid squares (15′ x 15′; QDS) and calendar month. From these data, an index of abundance (reporting rate) for each species within a quarter-degree square can be derived from the ratio of positive record cards for that species to the total number of record cards. Of the 1241 QDS that fall within Namibia, 47.6 % had five or fewer record cards returned,

Table 1 General ecology of the study species (from Maclean (1993); Ginn *et al* (1989)).

Species	Length (cm)	Habitat	Food	Breeding season	Breeding system [†]	Nest	Clutch size
Hartlaub's francolin	25 - 28	Rocky koppies, mountain slopes, escarpment	Seeds, fruit, shoots, insects, snails	Apr - Aug; Nov - Feb	M	Scrape	3
Rüppell's korhaan	50 - 55	Barren gravel plains, semi-desert, desert	Insects, seeds, succulent leaves	Sept - Feb	M	Scrape	1
Rüppell's parrot	22 - 23	Dry woodland, watercourses, wooded hills	Seeds, flowers, fruit, buds, pods, shoots, larvae	Feb - May	M	Tree hole	3 - 4
Violet woodhoopoe	35	Tall trees along dry watercourses	Insects	Dec - Jan	C	Hole in tree or stump	3
Monteiro's hornbill	54 - 58	Arid rocky / hilly country with savannah woodland	Insects, rodents, fruit, shoots, pollen	Feb - Mar	M	Hole in rock face or tree	3 - 5
Carp's black tit	15	Bush and tree savannah	Insects, seeds	Nov - Jan	C	Soft material in tree hole	4 - 5
Barecheeked babbler	24	Dry watercourses, wooded hills and woodland	?	Nov - Dec	C	Grass bowl in tree fork	2
Herero chat	17	Mountain slopes, escarpment hillsides	Small insects, berries	Feb - Apr	M	Bulky cup in tree or bush	1 - 2
Rockrunner	23 - 27	Rocky slopes of hills and mountains	Insects (beetles and grasshoppers)	Dec - Mar	M	Grass cup in grass tuft	2 - 3
Whitetailed shrike	15	Scrubby savannah, thornbush	Insects	Jan - Apr	M	Grass cup in fork of tree	1 - 3

[†] M - monogamous pairs; C - co-operative breeding

including 3.2 % squares which were not covered at all (see also Table 16, p 66). Although many of the endemic species are not well covered by SABAP, this database provides, in many cases, the only data currently available on the limits of bird distributions and relative abundances, and is thus an invaluable source of baseline information.

Figure 1 - Figure 10 are distribution maps for the 10 species included in this project, derived from SABAP records.

Previous research

Some aspects of the endemic species have been studied or recorded previously. These include the breeding biology of the Herero chat (Jensen and Jensen 1971); comparative research on the breeding biology of hornbills, including Monteiro's hornbill (Stanback in prep); notes on the rockrunner (Clinning and Tarboton 1972); and research on the ecology and behaviour of Hartlaub's francolin (Komen 1990). The ecology and behaviour of Rüppell's parrot is currently being studied (R. Selman pers. comm.).

A previous study has attempted to derive population estimates for some of Namibia's endemic birds (Robertson 1993; Robertson *et al* 1995). Line transect sampling was undertaken over an approximately six week period, within 56 QDS. Insufficient data were collected to calculate population sizes using environmental correlates alone; instead, analyses focused primarily on attempting to derive relationships between estimated bird abundances and SABAP reporting rates. Deriving such a significant relationship would allow population estimates to be made using atlas data alone. Data were sufficient to test this relationship for four of the 10 species sampled (whitetailed shrike, Monteiro's hornbill, Rüppell's parrot and rockrunner). For three of the species, significant positive relationships were obtained between estimated abundance and reporting rates. The resulting equations were used to estimate the following values of population size across the whole country: whitetailed shrike 357 347 ± 1 483; Monteiro's hornbill 110 312 ± 3 753; Rüppell's parrot 9 700 ± 3 915; rockrunner 13 489 ± 3 915. Overlap in the distributions of the 10 species was then assessed using atlas data as a measure of species presence or absence within QDS. The resulting map of endemic hotspots showed that only two squares (neither of which was within a protected area) contained all 10 species, while only 98 QDS contained five or more endemic species, most of these being along the Namibian escarpment and outside protected areas.

Figure 1 Southern African Bird Atlas Project reporting rates: Hartlaub's francolin.

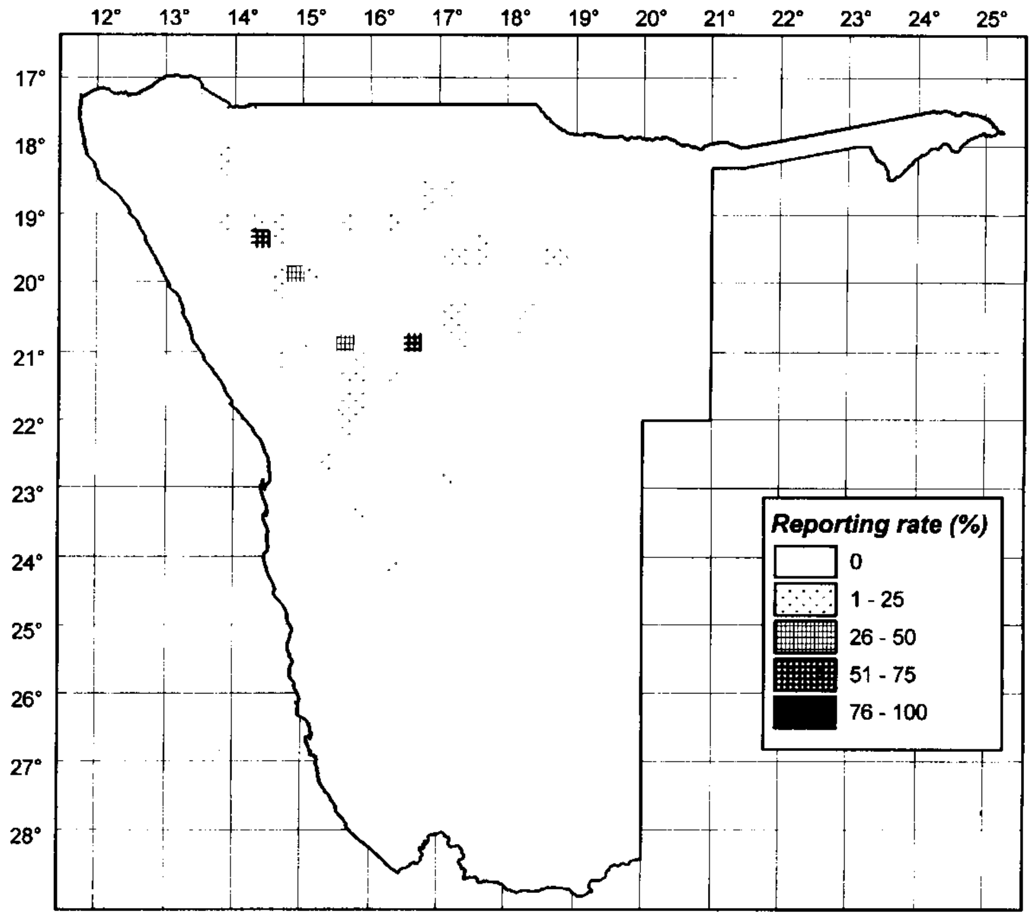


Figure 2 Southern African Bird Atlas Project reporting rates: Rüppell's korhaan.

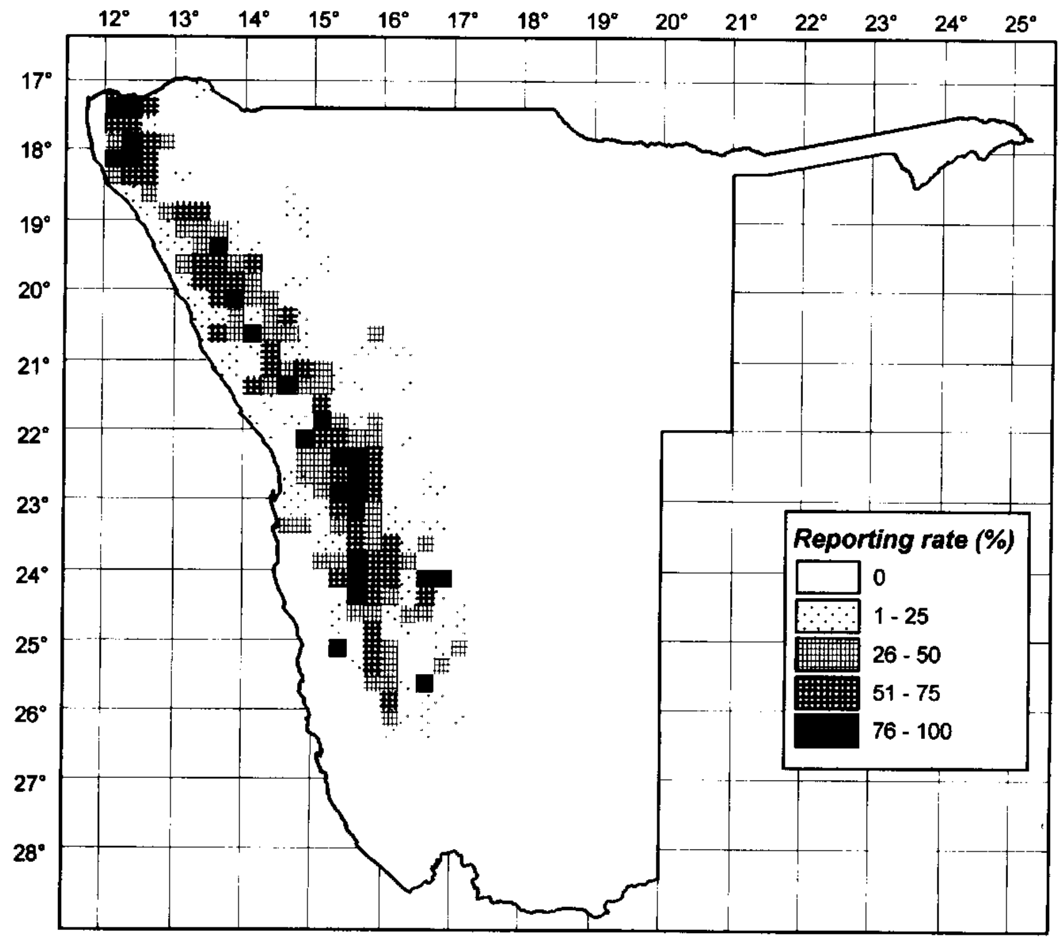


Figure 3 Southern African Bird Atlas Project reporting rates: Rüppell's parrot.

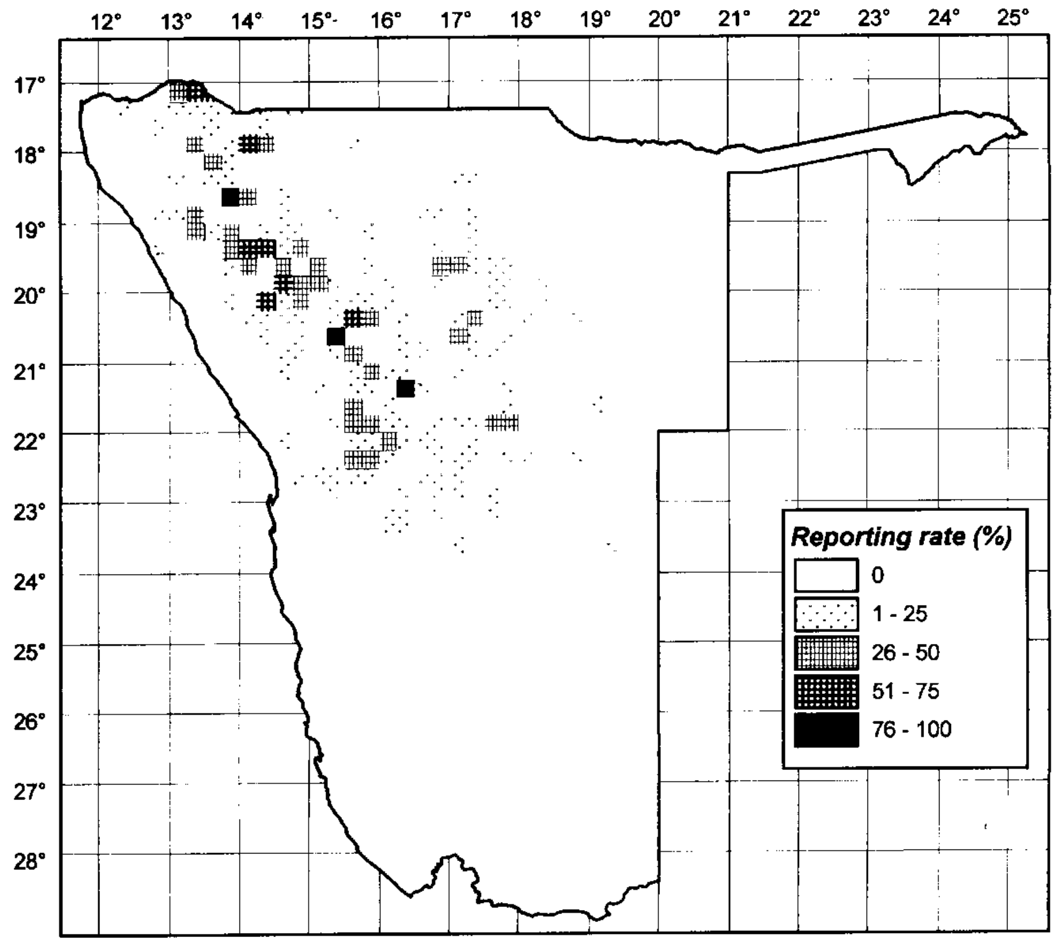


Figure 4 Southern African Bird Atlas Project reporting rates: violet woodhoopoe.

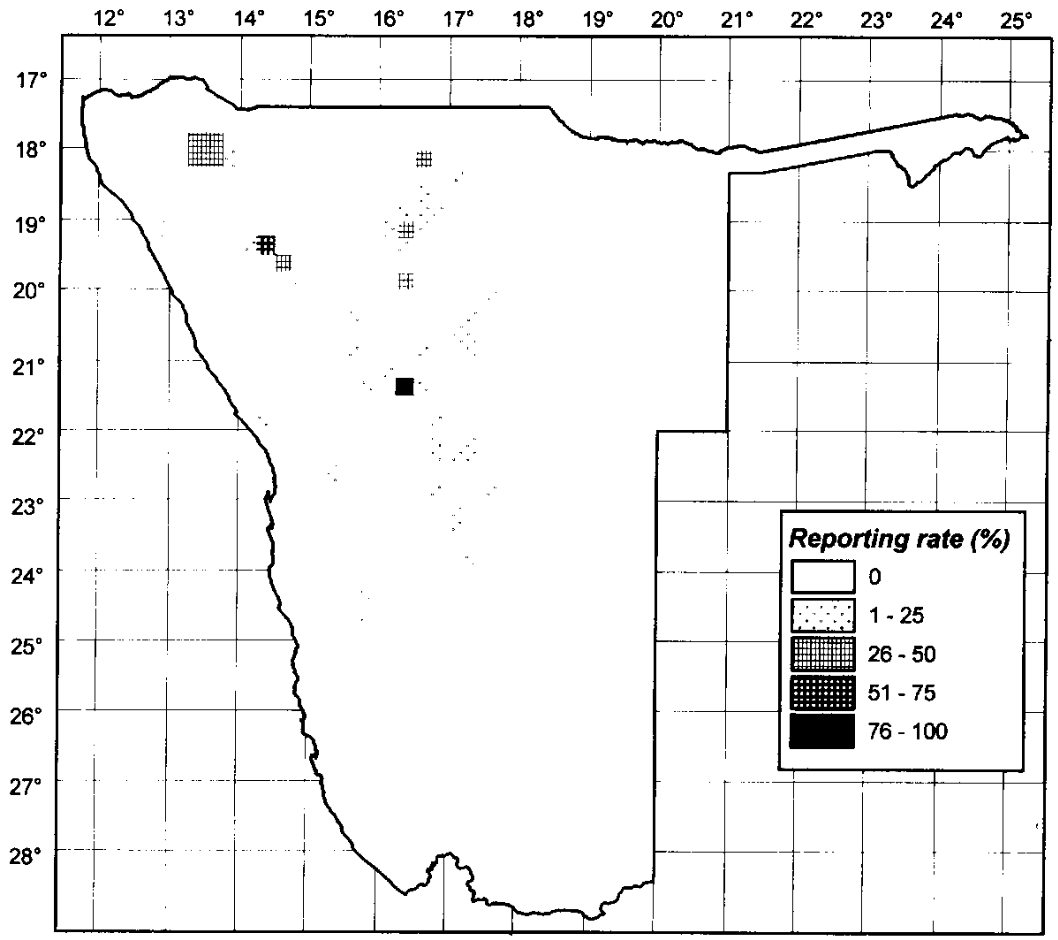


Figure 5 Southern African Bird Atlas Project reporting rates: Monteiro's hornbill.

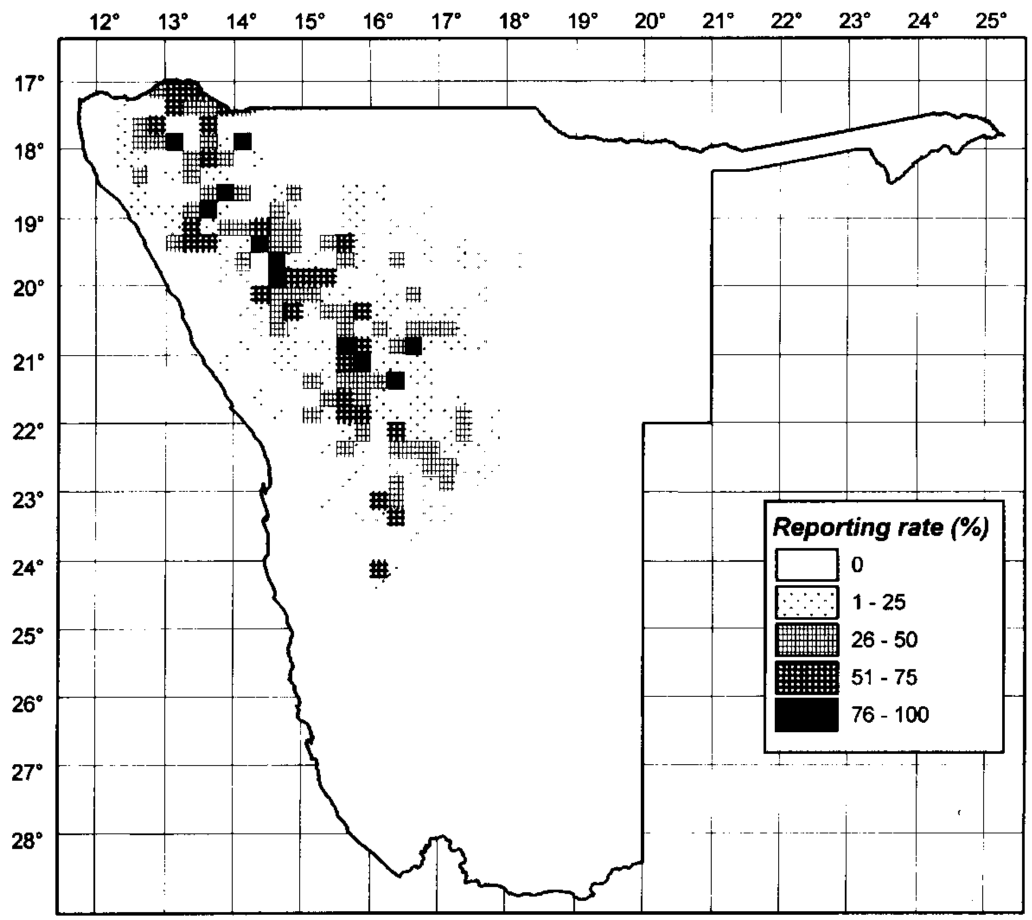


Figure 6 Southern African Bird Atlas Project reporting rates: Carp's black tit.

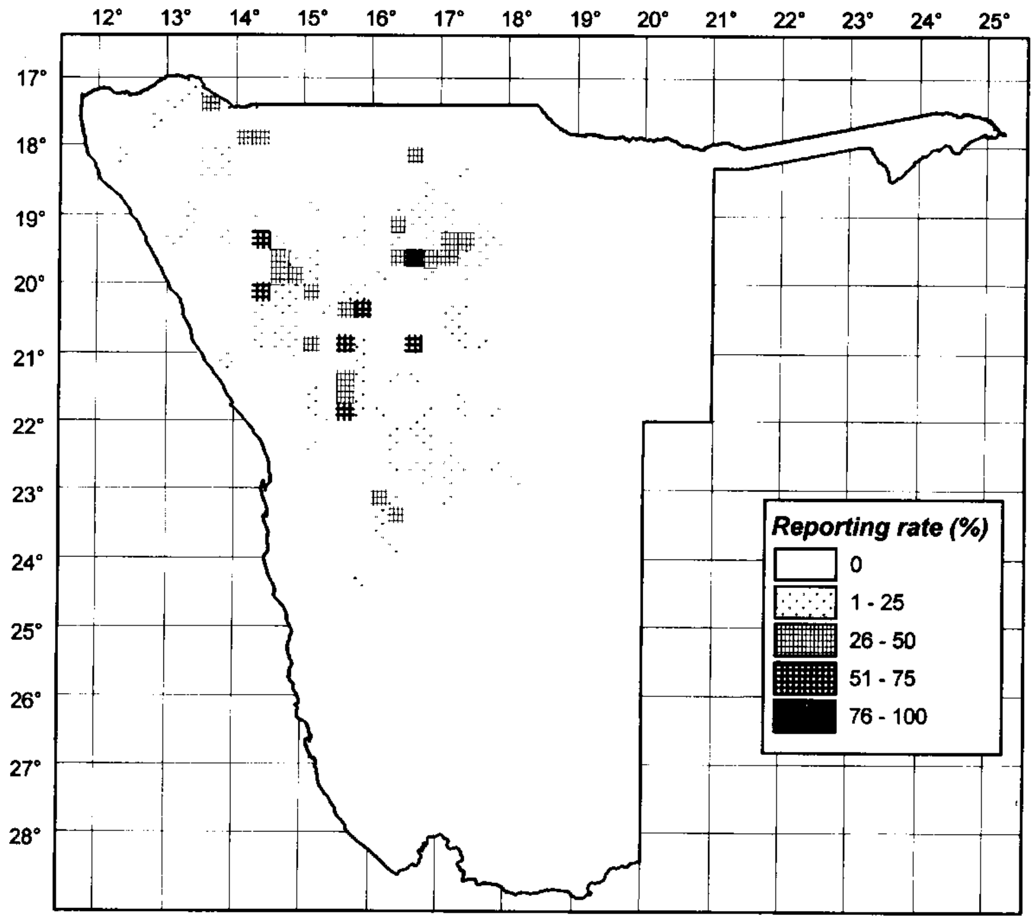


Figure 7 Southern African Bird Atlas Project reporting rates: barecheeked babbler.

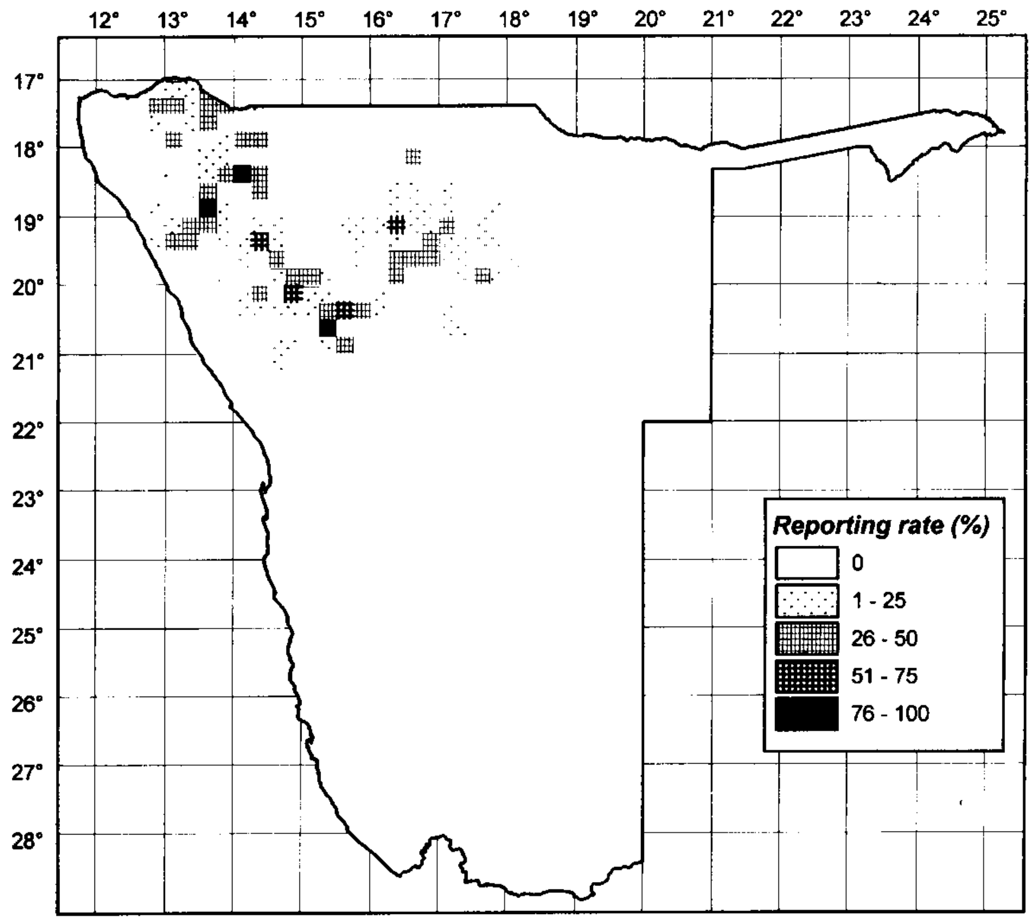


Figure 8 Southern African Bird Atlas Project reporting rates: Herero chat.

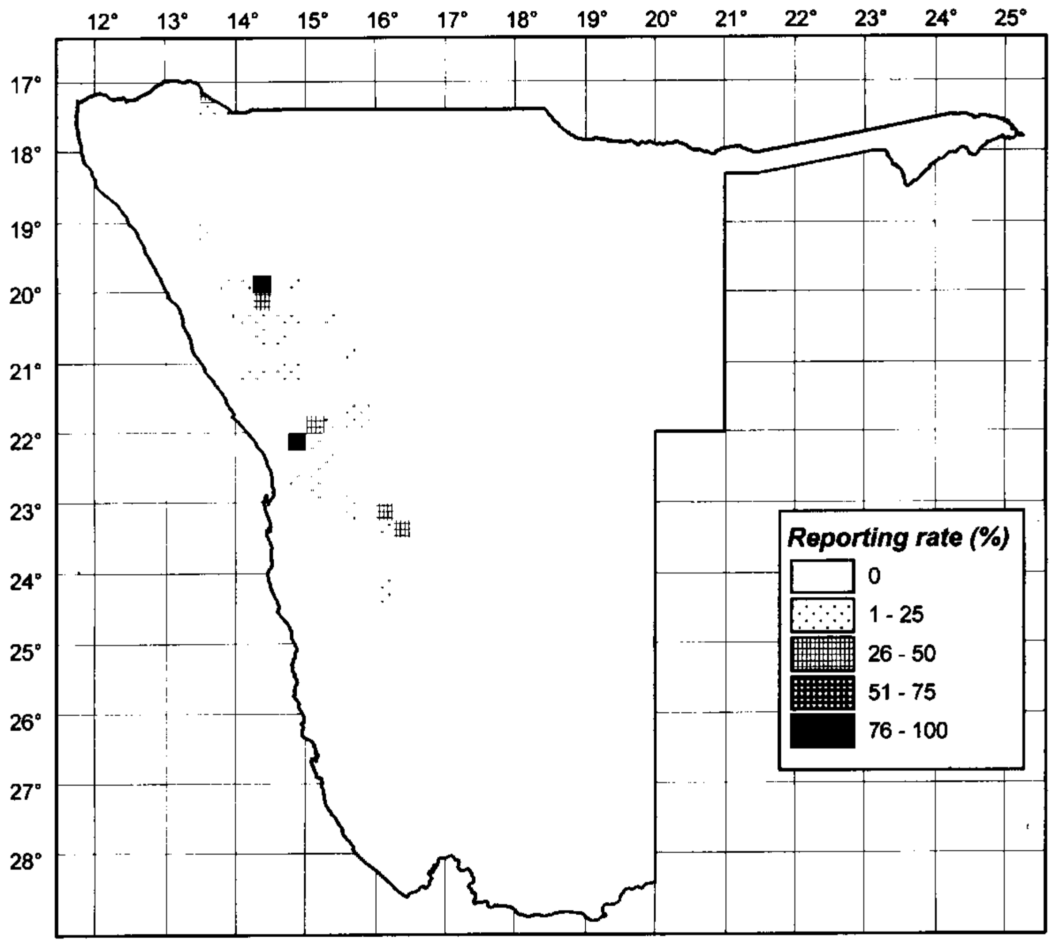


Figure 9 Southern African Bird Atlas Project reporting rates: rockrunner.

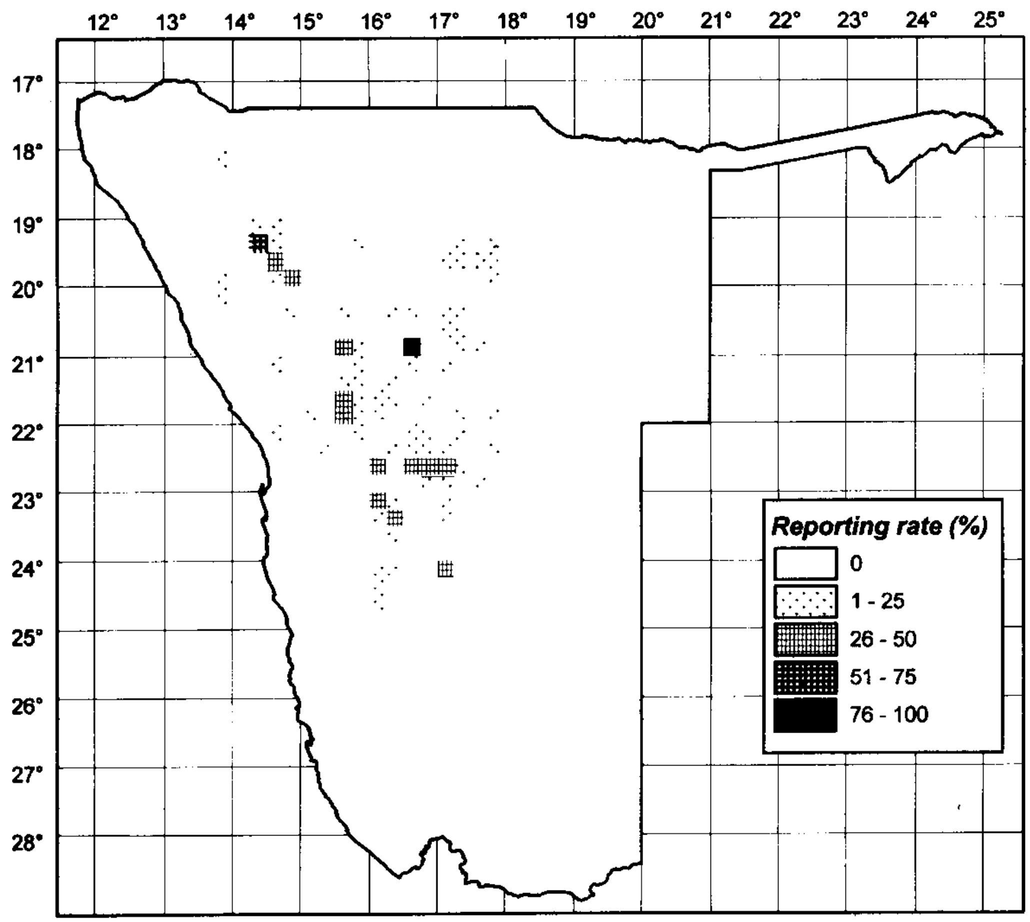
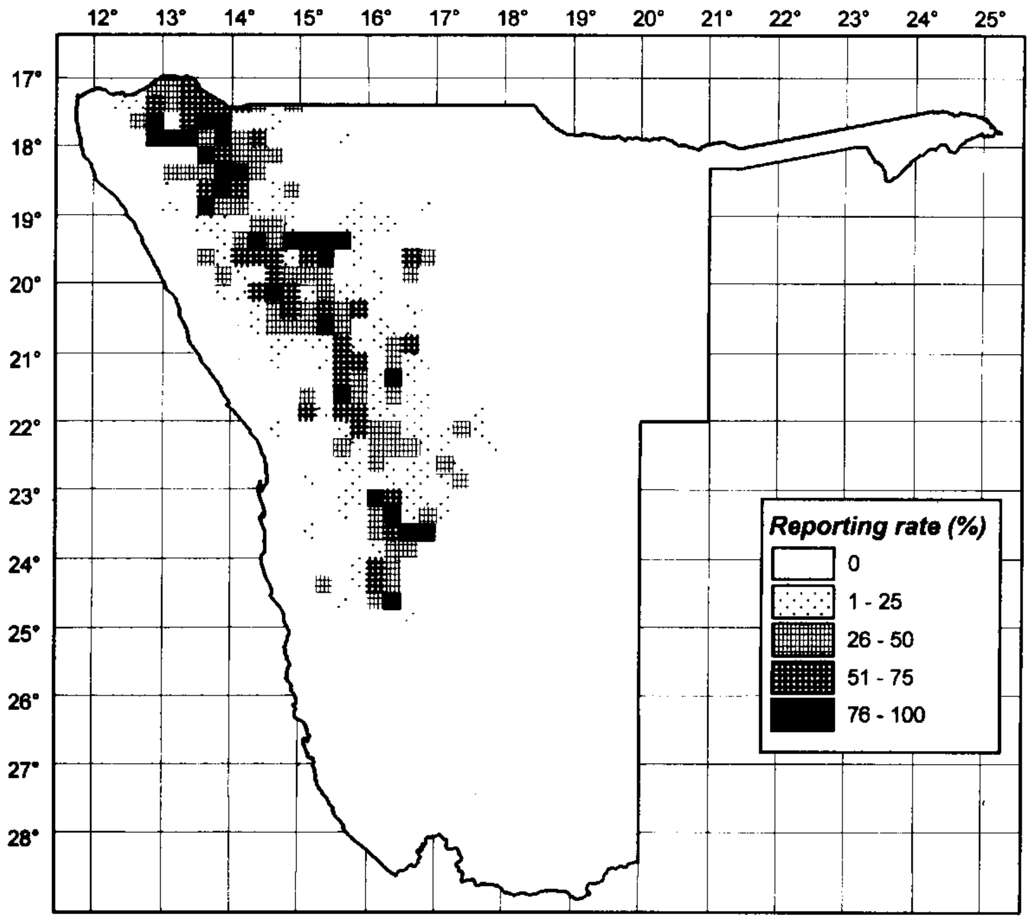


Figure 10 Southern African Bird Atlas Project reporting rates: whitetailed shrike.



Aims of this study

The work presented in this report was conceived as a follow-on study from our previous work, with the overall aim of obtaining sufficient data to undertake analyses for all 10 species surveyed. The four main aims of the study were to:

1) map the distribution and abundance of each species within Namibia;

2) estimate population size for each species at a national level, and to assess population status within protected areas and within different land-use units;

3) identify diversity centres or hotspots (Important Bird Areas) of endemic birds in Namibia, including information on the numbers and densities of each species within them; and

4) produce recommendations for a) conservation management action; b) any additional research; and c) short- to long-term monitoring.

Overview of chapters

Chapter 2 describes the methods used to obtain estimates of density for each species within its range, including information on the methodology used in data collection and control transects, line transect data collected, and numbers of birds recorded. The derivation of regression equations between environmental variables and bird density for riverine and non-river transects is described. In Chapter 3 a GIS (Geographical Information System) is used in conjunction with the density values predicted by the regression equations to map species' distributions. Total population sizes of each species, and numbers within different land use categories, are calculated. In Chapter 4 the QDS containing 'hotspots of endemism' are identified and mapped. The implications of the results with respect to factors such as conservation status and management, the viability of each species, effectiveness of protected areas and the optimal siting of a new conservation area, are discussed. Recommendations regarding the monitoring of the 10 endemic bird species included in this study are made in Chapter 5. A method which utilises the relationship between SABAP reporting rates and bird density is suggested for some species and recommendations for further research are made.

Chapter 2: Methods

Selection of areas for data collection

Field sampling for this study was undertaken within the QDS grid system used by SABAP. The QDS in Namibia are of the order of 27 x 27 km. For each species, squares were initially selected to include those with the greatest numbers of record cards, a good range of SABAP reporting rates, and an even spread across the species' distribution. Each square was assigned a vegetation code reflecting the avi-vegetational zones designated by Allan *et al* (Table 2; Figure 12) and additional squares were then added to ensure that sampling could be undertaken in each extant combination of vegetation and altitude. This procedure resulted in a final selection of 60 QDS (Figure 11). The selection of squares ensured maximum overlap between species (thereby maximising sampling efficiency) and minimised sampling within adjacent squares (to avoid spatial contiguity).

Table 2 Vegetation zone codes assigned to quarter-degree squares.

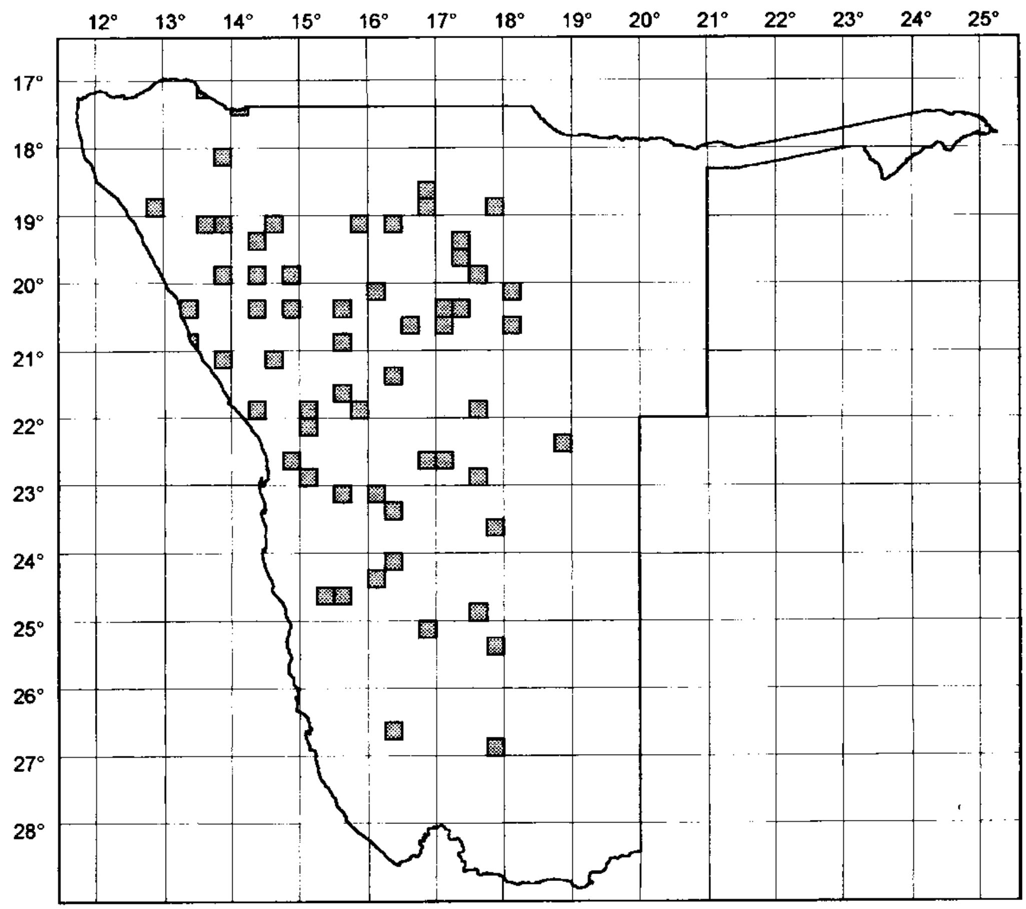
Code	Avi-vegetational zone	Brief description	Area (km^2)
Nam	Namib	coastal desert strip, sparsely vegetated	96 494
Esc	Namibian escarpment	semi-desert, characterised by species of *Acacia*, *Commiphora*, *Aloe*, *Euphorbia* etc.	124 484
Mo	Mopane	dominated by *Colophospermum mopane*	63 787
AW	Arid woodland	dominated by *Acacia* spp.	102 918
NK	Northern Kalahari	Kalahari system, characterised by	131 987
CK	Central Kalahari	dunes to the south and woodland to	60 996
SK	Southern Kalahari	the north	70 482
NKo	Nama Karoo	Karoo system, characterised by semi-	114 220
SKo	Succulent Karoo	desert dwarf shrubs	38 701

Data collection methodology

Bird count data were collected by line transect sampling, i.e. by an observer travelling along a defined and measured route and counting all birds detected. Transects were of variable length, depending primarily on the difficulty of the terrain, but an average of 41.4 km was sampled per square. Absolute perpendicular distances to birds from the transect line were measured, rather than using band widths, to allow the most robust form of density analysis of the data. This technique has a number of advantages over other methods as it takes account of the drop-off in the detectability of birds with distance from the observer, and is statistically the soundest approach (Burnham *et al* 1981; Bibby *et al* 1992). However, in using this approach the following assumptions are made (Anderson *et al* 1979):

1) birds on the transect line are detected with certainty;

Figure 11 Quarter degree squares (QDS) in which sampling was undertaken (n = 60).



2) if possible, a minimum of 40 bird observations are made;
3) clusters of birds are treated as one observation;
4) there is no movement of birds in response to the observer;
5) no bird is counted more than once; and
6) the population surveyed is not correlated with the sample line transects.

Transect lengths were calculated using either a Global Positioning System (Garmin International 1994) or a vehicle odometer. All GPS distances are measured to the nearest 10 m and have an error of ± 15 m. Perpendicular distances to the birds from the transect line were either measured with a GPS or were paced by the observer. GPS measurements were used where the error from pacing might be substantial, such as when distances from birds to the transect line were large, or in undulating terrain. Where distances were shorter and the GPS error would be relatively high, distances were paced by the observers and converted to the nearest meter, using a conversion factor based on several comparisons of paced versus measured distances. While transects should ideally be sited randomly within squares, this was not practically possible. Instead, the location of transects within a square was essentially arbitrary and transects were undertaken in a number of different locations within the square to minimise the effect of local variability. Where possible, the number of transects undertaken in each altitude zone was proportional to the area falling in that altitude zone.

Birds were detected by a combination of sight and sound (Table 3). During each transect, recordings of bird calls and alarms (Gibbon 1991) were played regularly on a portable tape player, in addition to whistling and imitation of calls by the observer(s). Response to calls was in most cases consistent.

Table 3 Attributes of the species in relation to detectability.

Species	Group sizes observed			Typical order of detection	Typical song or call	Response to observer or tape
	Mean	Min	Max			
Hartlaub’s francolin	2.1	1	7	sound, sight	duet	duet /solo call
Rüppell’s korhaan	2.3	1	6	sound or sight	duet / solo call	duet / solo call
Rüppell’s parrot	1.7	1	5	sound, sight	contact call	none / fly away
Violet woodhoopoe	3.5	2	5	sound, sight	group call	call / display
Monteiro’s hornbill	1.7	1	5	sound or sight	duet	duet / solo call
Carp’s black tit	2.3	1	8	sound, sight	song / trill	alarm call
Barecheeked babbler	6.0	2	15	sound or sight	group call	group call
Herero chat	1.9	1	3	sound, sight	song	alarm / song
Rockrunner	1.2	1	3	sound, sight	song	alarm / song
Whitetailed shrike	1.8	1	7	sound or sight	whistle	alarm call

Rivers depicted by double dashed, or dark dashed lines, on the 1 : 250 000 relief map series were classified as 'major' whilst those depicted as single dashed lines were classified as 'minor'. Minor rivers are generally less than 50 m wide and do not support significant riparian vegetation. No endemic riverine species such as barecheeked babbler and Rüppell's parrot had previously been observed in association with minor rivers (Robertson 1993), so no distinction was made between these rivers and the surrounding land.

Data from each transect were recorded onto a printed check-sheet (Appendix 1). All sampling was undertaken using the line transect methods described above. However, several different categories of line transects were utilised to take account of differences in the ecology of the 10 species and to maximise sampling efficiency. These are listed in Table 4.

Table 4 Transect categories utilised during line transect sampling.

Species included	Transect category
All species except Rüppell's korhaan and Hartlaub's francolin	N
Hartlaub's francolin only	F
Hartlaub's francolin and Carp's black tit only	FT
All species except Rüppell's korhaan	FN
Rüppell's korhaan only	K
All species except Hartlaub's francolin	KN
All species	FKN
All species within major rivers	R

Using different types of transects enabled greater flexibility. For example, in areas with high densities of some species (typically whitetailed shrike and Monteiro's hornbill), focusing on only one or two species allowed a greater transect distance to be covered and a greater number of detections to be made of these focal species. Transects including Hartlaub's francolins were undertaken during the few hours after sunrise and before sunset as these birds are most vocally active during the crepuscular hours. Because of the generally low densities of Rüppell's korhaan, 'korhaan' transects were driven rather than walked, with one observer seated on the roof of the vehicle. In this way detection distance, and therefore the number of korhaans recorded, was increased. Road counts were undertaken only on minor or gravel roads. To comply with National Park regulations, all transects within Etosha National Park and on the Waterberg Plateau were driven.

Information about the sampling undertaken in each vegetation zone is given in Table 5. Because very few records of endemics were made in the Kalahari and Karoo vegetation zones during the extensive period of data collection for SABAP, only minimal sampling was done in these zones in this study. The three Kalahari vegetation zones were quite obviously unsuitable for any of the 10 species, and little time was spent in these zones.

Table 5 Total lengths of line transects in each vegetation zone.

	Vegetation zone								
	Nam	Esc	Mo	AW	NK	CK	SK	NKo	SKo
Distance walked (km)	41	636	71	354	9	37	0	0	0
Distance driven (km)	387	342	340	45	0	0	29	136	58
Total length (km)	428	978	411	399	9	37	29	136	58

Because of the relatively low numbers of sightings of Hartlaub's francolins during sampling, transects undertaken during a previous study (Robertson 1993) were amalgamated with the present data set. This increased the numbers of Hartlaub's francolins included by 66 (34 clusters), and the number of transects by 34. As seasonal and temporal effects are likely to be minimal for this species, we considered that adding these data would not introduce significant bias. For the remaining species, the potential for introducing significant bias by amalgamating data sets was considered to be greater than the potential benefits. Table 6 lists the numbers of birds observed during transects.

Table 6 Observations of endemic birds made in each vegetation zone during sampling.

Species	Vegetation zone									
	Nam	Esc	Mo	AW	NK	CK	SK	NKo	SKo	Total
Number of birds observed										
Hartlaub's francolin	0	29	43	58	0	0	0	0	0	130
Rüppell's korhaan	28	145	0	0	0	0	0	4	0	177
Rüppell's parrot	0	66	19	18	4	0	0	0	0	107
Violet woodhoopoe	0	25	18	11	0	0	0	0	0	54
Monteiro's hornbill	0	190	66	202	0	0	0	0	0	458
Carp's black tit	0	111	82	67	0	0	0	0	0	260
Barecheeked babbler	0	167	102	27	0	0	0	0	0	296
Herero chat	0	120	0	0	0	0	0	0	0	120
Rockrunner	0	34	7	101	0	0	0	0	0	142
Whitetailed shrike	0	588	152	96	0	0	0	0	0	836
Number of groups (clusters) observed										
Hartlaub's francolin	0	17	17	29	0	0	0	0	0	63
Rüppell's korhaan	13	61	0	0	0	0	0	2	0	76
Rüppell's parrot	0	36	11	13	3	0	0	0	0	63
Violet woodhoopoe	0	7	3	3	0	0	0	0	0	13
Monteiro's hornbill	0	112	39	119	0	0	0	0	0	270
Carp's black tit	0	49	30	34	0	0	0	0	0	113
Barecheeked babbler	0	30	18	6	0	0	0	0	0	54
Herero chat	0	63	0	0	0	0	0	0	0	63
Rockrunner	0	32	6	85	0	0	0	0	0	123
Whitetailed shrike	0	315	80	61	0	0	0	0	0	456

Calculation of bird density estimates

Non-river transects

Most of the data handling stages and Fourier series analyses were carried out using QBASIC programming procedures (Microsoft Corporation 1988). In addition to the vegetation code (Table 2) each transect was assigned a code for each of the environmental variables listed in Table 7.

Table 7 Environmental variable codes assigned to each transect.

Variable	Code	Description	Source
Altitude	100	0 - 199 m	South West Africa
	300	200 - 399 m	1 : 250 000 topographical
	to	to	sheets, Surveyor-General,
	2500	2 400 - 2 599 m	Windhoek
Rainfall	50	0 - 99 mm	10 year average rainfall
	150	100 - 199 mm	map, Remote Sensing
	to	to	Centre, Windhoek
	650	600 - 699 mm	
Average minimum	1.5	< 2 °C	Van der Merwe (1983)
monthly	2.5	2 - 3 °C	
temperature	3.5	3 - 4 °C	
	to	to	
	9.5	9 - 10 °C	

Each unique combination of selected variables was assigned a code which was used to group the transects into classes, taking account of the transect categories described in Table 4. Density values were then calculated for each of these classes using a Fourier series (Burnham *et al* 1981) as follows:

Values for the Fourier coefficient (a_k) were calculated using the equation:

$$a_k = (2 / nw) (\Sigma \cos (\pi kx / w)$$

where $k = 1, 2, 3$ etc.
n = number of birds
w = cut-off distance
x = perpendicular distance to each bird

For each species, the cut-off distance, w, was taken to be the perpendicular distance which excluded obvious outliers, resulting in values which excluded between 0 and 3.1 % of records. Appendix 2 illustrates detection distances for each species, and w values used. For all species except whitetailed shrike, no differences in detection distances between vegetation zones were found and therefore only one value of w was calculated for each species. For whitetailed shrike, detection distances in Arid Woodland were significantly lower than in Escarpment and Mopane and hence two values for w were calculated for this species.

The critical value was then calculated and compared with the value of the Fourier coefficient as follows:

$$1 / w (2 / n + 1)^{½} \geq \text{abs} (a_{m+1})$$

where m = 0, 1, 2 etc. until the equation was satisfied

The f estimator was then calculated as:

$$f = a_q + 1 / w$$

where q is the sum of all m values excluding the final value

Finally, density (D) was calculated from:

$$D = nf / 2L$$

where L = transect length.

Each group (cluster) of birds encountered along transects was treated as a single observation and only one detection distance was measured. For each species, the final density value was multiplied by the average cluster size for the species (Burnham *et al* 1981). Final density values were converted from m^2 to km^2.

On the few occasions when the requirements of the above equations were not met (i.e. where the number of observations was low at the outer limits of a species' distribution), bird density was calculated using {(2w) * transect length}.

River transects

Major rivers were considered as linear features. As transects along the Kunene river only included birds on the Namibian (south) side, densities for those transects were multiplied by a factor of two to ensure comparability with other transects where birds on both sides were recorded. Transects along major rivers were assigned to unique classes using the same vegetation and environmental variables codes as for non-river transects. Density was then calculated as the number of birds per km of river.

Derivation of regression equations between bird density and environmental variables

Non-river transects

For each species, a regression equation was derived between estimated bird density and selected environmental variables. Because of the limitations of the transect data, no more than three variables were considered at a time, and the data were coded accordingly (e.g. by vegetation, altitude and rainfall). The distribution of each species across the country was significantly linked to vegetation zone (see Table 6); hence to examine the effect of vegetation zone *within* the distribution of a species, data were used only for those vegetation zones where that species was observed.

General linear models were used to determine which of the variables, and interactions between variables, were most important in influencing calculated density values of each species (normalised either by log (n + 1), or square root transformation). Vegetation was always considered to be a categorical variable whilst other environmental parameters were usually considered to be continuous variables. Degree of latitude and longitude were also considered as continuous variables. For continuous variables the midpoint of the range was entered into the model, for example, rainfall zone 0 - 99 mm was entered as 50 mm. For each species, a large number of combinations of environmental variables was assessed and the model which resulted in the highest significant R^2 (percentage variance explained) was retained and used for subsequent predictions of bird density. Error values for each predicted density estimate were calculated using the equations provided in Sokal and Rohlf (1981) for simple and multiple regression analyses (Appendix 3).

A summary of the regression models is given in Table 8 and the full models are detailed in Appendix 4. Vegetation was retained as a factor in the model for all species which occurred in more than one vegetation zone, with the exception of Carp's black tit and Monteiro's hornbill. For these species, the best model was one in which rainfall was used as a category. Although violet woodhoopoes are predominantly found in association with major riverine systems it is apparent that some groups do occur away from major rivers, typically in association with waterholes or springs (e.g. Halali rest camp, Waterberg). However, there were insufficient sightings of this species in non-river transects to enable non-river densities to be calculated.

Table 8 Environmental variables which influenced bird densities in non-river transects.

Species	Variables retained	R^2 (% variance explained)
Hartlaub's francolin	vegetation, altitude	86.9
Rüppell's korhaan †	vegetation, rainfall	51.3
Rüppell's parrot	vegetation, altitude	47.3
Monteiro's hornbill	rainfall, altitude	56.6
Carp's black tit	rainfall, altitude	68.9
Barecheeked babbler	vegetation, altitude	52.2
Herero chat	altitude	51.0
Rockrunner	vegetation, altitude	76.9
Whitetailed shrike	vegetation, rainfall, altitude	75.7

† Because of the low rainfall throughout the range of Rüppell's korhaans, 50 mm rainfall bands were used for this species.

River transects

Determination of the environmental variables most important in influencing the number of birds per km of river was undertaken in a similar way to the analysis of non-river transects. However, because there were relatively few observations within rivers for most species, only one variable was considered at a time. River densities (birds / km) were calculated for all species except Herero chat and Hartlaub's francolin, which were absent along rivers, and Rüppell's korhaan, which was not present in sufficient numbers to enable density values to be calculated.

A summary of the regression models is given in Table 9 and the full models are detailed in Appendix 5.

Table 9 Environmental variables which influenced bird densities in river transects.

Species	Variables retained	R^2 (% variance explained)
Rüppell's parrot	rainfall	74.7
Violet woodhoopoe	rainfall	55.0
Monteiro's hornbill	rainfall	94.7
Carp's black tit †	-	-
Barecheeked babbler	rainfall	57.0
Whitetailed shrike	altitude	66.6

† Too few observations (n = 13) of Carp's black tit were made within rivers to derive a satisfactory relationship between density and any environmental variable(s). Therefore average densities were calculated for each vegetation zone, as 0.309 birds per km (s.e. 0.111) in the Escarpment and 0.576 birds per km (s.e. 0.355) in Mopane.

Potential sources of bias in sampling methodology

Bibby *et al* (1992) identify a number of potential sources of bias in line transect sampling which may significantly influence derived bird density estimates. Potential observer effects include differences in observer ability and variations in effort and speed. Factors potentially affecting the reliability of bird detection include differences between habitats and species, variations in bird density, effects of time of day, weather and seasonal differences on bird activity.

Observer ability and variations in effort and speed

Bias was minimised by using two observers of similar ability, equally experienced in the methodology and familiar with the birds, songs and calls before the start of the project. Transects were walked at relatively consistent speeds and time per transect (effort) was recorded.

Differences between habitats and species

Birds were detected mainly by sound, thus reducing the effect of variability between habitats. These species are present and audible all year round at densities which are rarely high enough to cause confusion.

Effect of time of day, and weather, on detection of birds

The time recorded at the beginning and end of each transect was used to calculate the number of hours from sunrise (or hours to sunset) for each sighting of a bird or group of birds. Spearman's rank correlation was used to examine the effect of time on the proportion of sightings made in each time zone, using all data. There were no obvious trends, suggesting that bird detections did not consistently either significantly increase or decrease with time during the morning and afternoon sampling periods. Time of day was therefore not considered to have significantly influenced detection of birds. Transects were not undertaken during adverse weather, such as high winds, or during the hottest part of the day.

Effect of season on detection of birds

The effect of season on bird distributions within their ranges may have influenced the number, distribution or activity of birds seen during our field sampling. For example, species such as Rüppell's korhaan might move into areas where there is increased vegetation growth as a result of recent rainfall. As we sampled widely across the species' distributions this should not affect the total population estimates but might influence the estimated abundances within their distributions. To assess whether the 10 species move significantly with season, SABAP data for squares with more than 30 cards and positive records for that species were selected. Records within the period from January to April were designated as 'rainy season' and those between May to September were designated 'dry season'. Reporting rates were then calculated for each species for the two 'seasons'. For each species, a general linear model was used to examine separately the interaction between season and both latitude and longitude on reporting rate. There were no significant interactions between season and either latitude or longitude for any species, suggesting that movement with season is minimal or, more probably, that movement varies over years according to rainfall rather than following a regular pattern related to calendar month.

Assessment of sampling accuracy: control transects

Bibby *et al* (1992 p 33) observed that 'many bird census studies do not measure their precision at all and even a pragmatic aim of measuring it and trying to get within 25% of the true value would be an improvement'. To obtain some measure of how accurately the sampling methodology produced estimates of actual density, a control was undertaken.

The control was undertaken within a QDS where eight of the 10 species (all except Rüppell's korhaan and Herero chat) have relatively high SABAP reporting rates. An area of approximately 5 km^2 was defined and sub-divided into five discrete sections. Transects were walked through each of the five sections providing a total transect distance of 14.46 km. The control area was then intensively searched over three days by two observers walking parallel to each other and counting all endemic birds detected. Walking speed and parallel distance were chosen to ensure that all birds were detected but not double counted. We are confident that all endemic birds within the control area were detected. Despite five of the 10 species being observed within the control area, sufficient observations to obtain bird densities were made only for whitetailed shrike. The control area was digitised on a GIS and the actual population density was calculated as 20.24 whitetailed shrikes per km^2 (calculated from the presence of 103 birds, in a total area of 5.09 km^2). The estimated density of birds calculated from the line transects was 17.00 ± 4.37 per km^2 (calculated from observations during line transect sampling of 24 clusters, 55 birds). Error for the estimate was calculated using the equations described in Burnham *et al* (1981). While our estimated density was an underestimate of the true density, the fact that this value falls within the calculated error margin (12.63 - 21.37) suggests that values predicted using this relationship should include the true density value

Because of the generally low density of endemics, it is difficult to find areas suitable for controls of other species: for example even in the area with the *highest* Rüppell's korhaan density (3.21 groups / km^2) over 12 km^2 would need to be intensively searched to make 40 observations of korhaans. This is not practical in a study of this scale and we have therefore assumed that our methods (and derived estimates) are equally adequate for the remaining species sampled.

Chapter 3: Calculation of bird abundance using environmental variables

Prediction of density from environmental variables

Bird abundance and, ultimately, total population size was estimated using a Geographic Information System (GIS). Maps of the three environmental parameters (vegetation, altitude and rainfall) retained by the regression models derived in Chapter 2 were manipulated in ARC / INFO (E.S.R.I. 1989). All maps used for GIS manipulations were projected using Albers equal area projection using the parameters appropriate to the country; however, all maps illustrated in figures remain unprojected (geographic projection). The outlines of the avi-vegetational zones defined by Allan *et al* were defined in a vegetation coverage (Figure 12). The altitude coverage comprised contour intervals of 300 m (Figure 13), while rainfall was delimited by isohyets of 10 mm, beginning at 50 mm (Figure 14). The rainfall and altitude coverages were provided by the Remote Sensing Centre, Windhoek and the avi-vegetational zones coverage was provided by the Avian Demography Unit, University of Cape Town. These three coverages were combined to form one spatial layer containing over 5 000 polygons, each defined in terms of the combination of vegetation, altitude and rainfall. Major river courses were digitised from the 1 : 250 000 South-West Africa series of topographical maps (Figure 15) and the length of river having each unique combination of variables was calculated. Table 10 shows the length of major river courses within each vegetation zone.

Table 10 Lengths of major river courses within each vegetation zone.

Avi-vegetational zone	Length (km)
Namib	3 994
Namibian escarpment	2 807
Mopane	292
Arid woodland	971
Northern Kalahari	38
Central Kalahari	57
Southern Kalahari	65
Nama Karoo	398
Succulent Karoo	0
Total	8 622

The regression relationships for non-river areas were used to obtain predicted densities and their associated errors (birds / km^2) for each species for each polygon. Predicted bird numbers and errors (birds / km) for species within major river courses were calculated from the regression relationships derived from river transects in a similar way. Values for rainfall and altitude inserted into the regression equations corresponded to the midpoints of class intervals dictated by the associated GIS coverages. For example, for an area falling within the 0 - 300 m altitude zone and 60 - 70 mm rainfall region, the density estimate for a species was predicted using altitude and rainfall values of 150 m and 65 mm, respectively.

Figure 12 Avi-vegetational zones within Namibia.

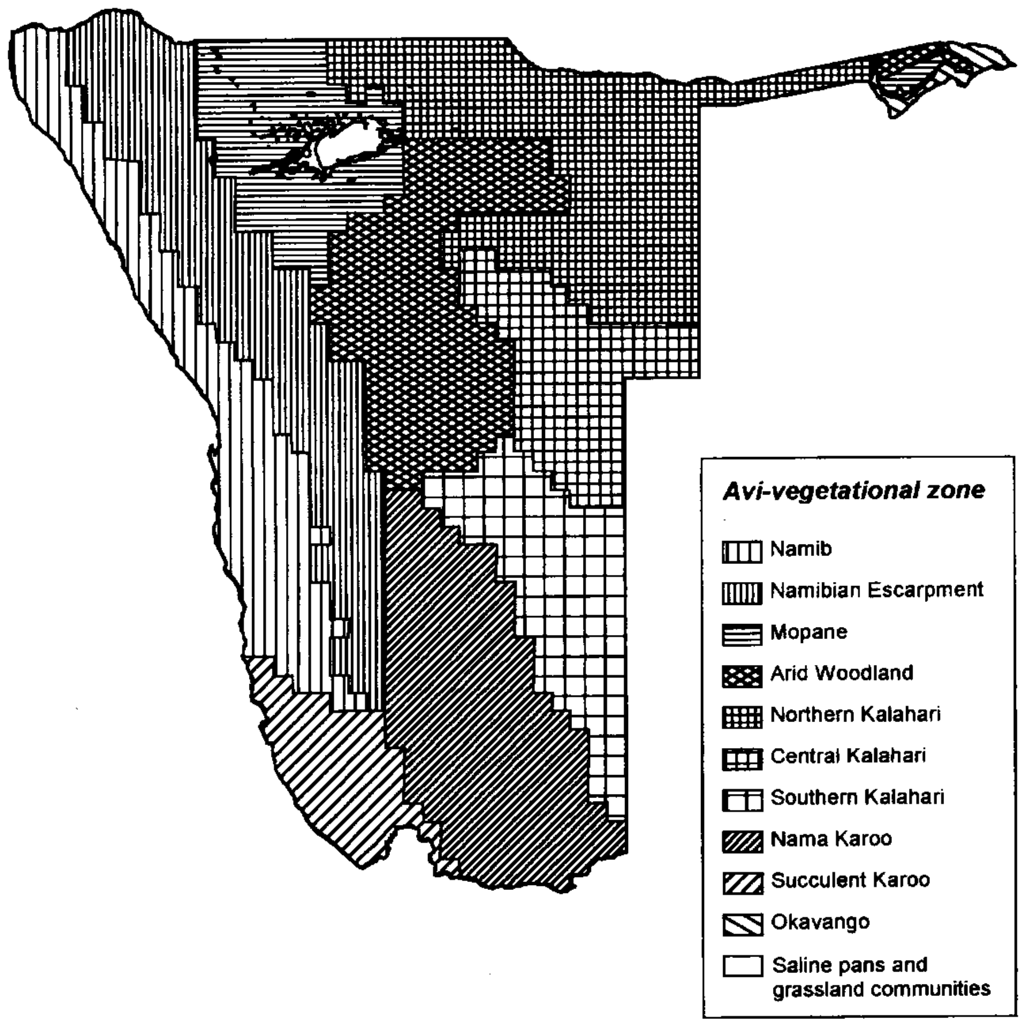


Figure 13 Altitude contours within Namibia.

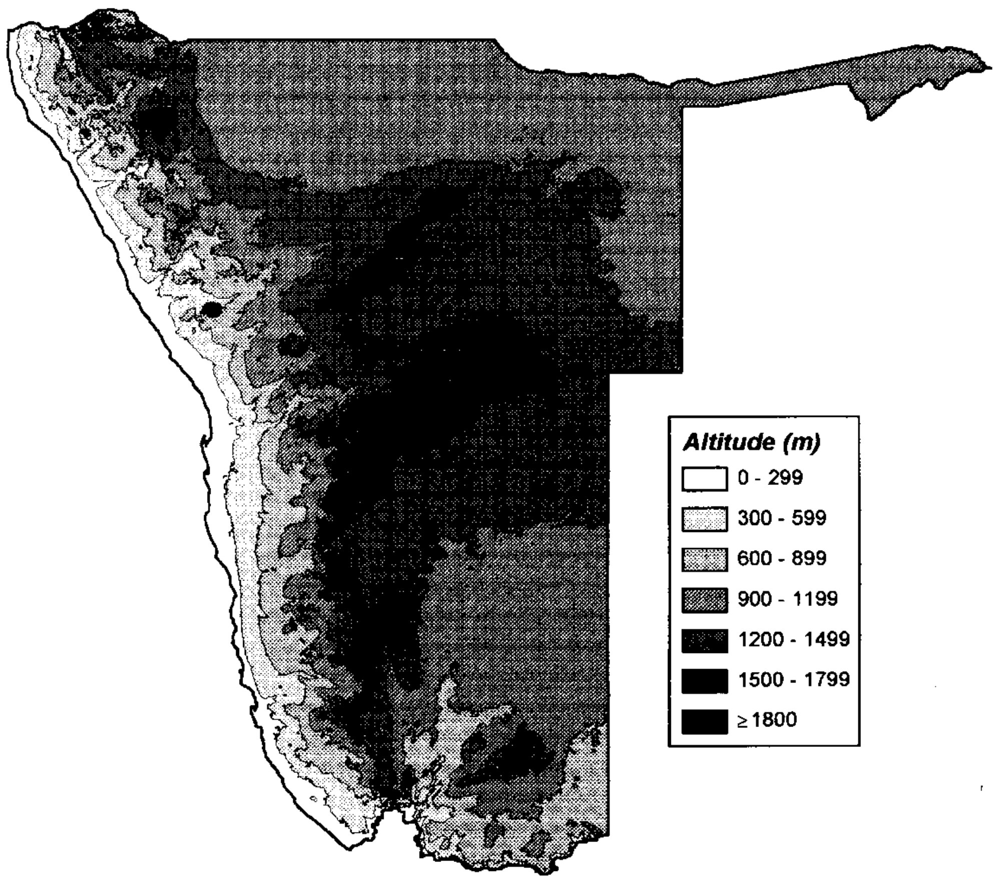


Figure 14 Rainfall isohyets within Namibia.

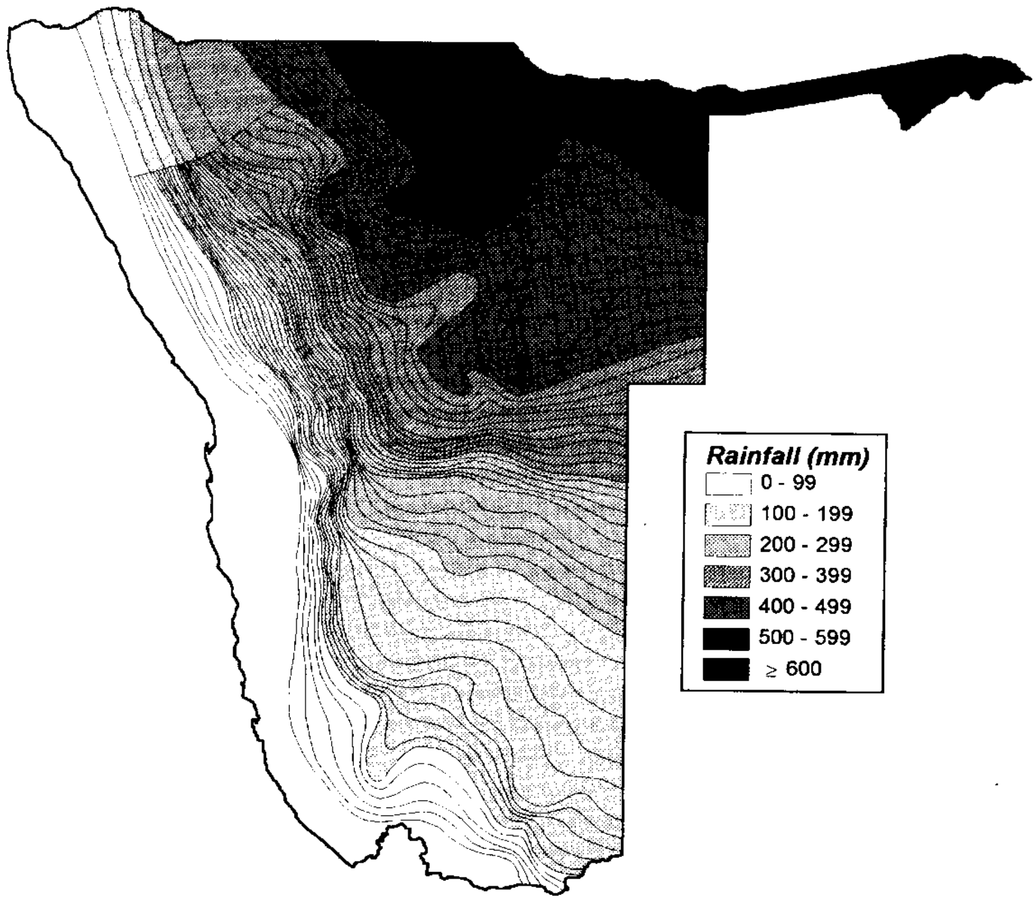


Figure 15 Distribution of major river courses within Namibia.

Assigning predicted values to spatial features

Non-river

For each species, predicted non-river densities and the associated errors for all unique combinations of variables were entered into the GIS and multiplied by the corresponding polygon areas to derive an abundance value for each polygon. This 'abundance coverage' thus contained a large number of polygons, each of known area and with an associated density and error for each species.

River

Similarly, the predicted bird density and associated error for birds along river courses within each combination of variables was multiplied by river length to derive an abundance value.

Exclusion of areas from extrapolations of predicted values

Extrapolating density values across all areas with the same combination of environmental variables is one way to estimate population sizes and distributions from relatively limited field sampling. Although this methodology is particularly suited to a country such as Namibia, where there is generally a high degree of homogeneity across large areas of land, the limitations of the approach need to be recognised. Extrapolating estimates of bird density across large areas must be undertaken with regard for the characteristics of the areas concerned and the likely limits to bird distributions. For example, a relationship between bird density and altitude is unlikely to be true indefinitely, and there is likely to be a point (height) at which the birds do not occur at all. These limitations must therefore be incorporated into the extrapolations. In order to take account of known variation in bird distributions not reflected in the environmental parameters used, and to obtain the best possible population estimates from the available data, we found it necessary to limit the extrapolations for several species by excluding selected areas. All excluded areas were attributed density and error values of zero for all species. Exclusions particular to single species are described in the discussions of results for the relevant species, while those applicable to all species are described below:

1. Brandberg, in the Escarpment vegetation zone, ranges from 400 m to over 2 500 m in altitude. Sampling was undertaken between 400 m and 1 000 m on the slopes at Brandberg and no endemics were observed above 600 m. As vegetation cover appears to decrease with altitude we assumed that the upper slopes are less suitable for any of the endemic species. Predicted values of zero were therefore entered for all species at altitudes above 600 m in the Brandberg.

2. Etosha National Park is entirely within the Mopane avi-vegetational zone and largely within one altitude zone (900 m - 1 200 m). Etosha pan and the other saline pans comprise almost one quarter of the park area and were categorised as a sub-zone in which we assumed none of the endemic species is present. However, in addition to the pans, there are significant differences in the vegetation and topology across the park which are likely to influence the density or occurrence of several of the species, particularly the more specialist endemics, such as rockrunner and Hartlaub's francolin. In order to maximise the accuracy of population estimates within Etosha, vegetation categories described by le Roux (1988)

were used to identify and exclude areas unsuitable for the endemics. The grassland communities, comprising Sweet grassveld on lime, Adoniveld, Okondeka duneveld, Poacher's peninsula, Ekuma grassveld, Omarumba onaiso and Karstveld turf pans, were clearly unsuitable for any of the species and were excluded. Of the remaining sub-types only Karst bush and forest and Kaokoveld (which are restricted to the southern section of the park) appeared to support birds of these species and consequently all other vegetation sub-types were excluded.

3. While the Mopane avi-vegetational zone is important for most of the species, the nature of the vegetation to the north and east of Etosha National Park changes, from mopane bushveld to mopane shrubveld. This vegetational change corresponds to a change in geology to the Kalahari lithostratigraphic group, and closely follows the 1 200 m altitude contour. The mopane zone east of the 1 200 m contour exists as a relatively flat expanse of shrubveld within which none of the 10 species was observed during sampling. There are also no SABAP records for these species in this area and, although this may be an artefact of the low numbers of reporting cards, it is unlikely that even poorly covered squares would not show records for easily observed species such as whitetailed shrike. This mopane shrubveld area was therefore excluded from extrapolations of bird densities.

4. Most species were restricted in their distribution to the Escarpment, Mopane and Arid woodland vegetation zones. The southern section of the escarpment is characterised by a lack of major river systems, and the relief in this area is significantly different from the northern section, where the effect of the river systems has resulted in many small gullies and small-scale topographical features. The absence of such features is likely to be important in restricting the distributions of those species which depend on rocky or undulating terrain and gullies (Herero chat, Hartlaub's francolin and rockrunner), as well as the riverine species (barecheeked babbler, Rüppell's parrot). None of the endemics, except Rüppell's korhaan, was observed in this southern section and therefore this area was excluded. For Rüppell's parrot, all areas south of the last major river course (the Kuiseb river) in the escarpment zone were excluded from the extrapolation of predicted values. For other species, the cut-off line was slightly further south, determined by our own observations in combination with SABAP records.

Prediction of abundance

After taking account of the exclusions listed above, estimated population sizes, with associated errors, were calculated for non-river birds by summing the abundance and error values for each polygon. River population estimates and errors were calculated similarly.

Total population size and total error were calculated for each species across the whole country by summing all the abundance and error values for both river and non-river areas.

Estimates of bird abundance for each species within different land categories, such as land tenure and vegetation zone, were produced by overlaying coverages of these features on the abundance coverage and calculating bird abundance in the relevant area. Figure 16 and Figure 17 show the locations of Namibia's National Parks and the distribution of land tenure, respectively. Table 11 shows the distribution of land tenure within vegetation zones.

Table 11 Distribution of land tenure within each avi-vegetational zone.

Zone	Land Tenure (area in km^2)					
	Commer-cial	Communal	Farms Communal	Mining Area	National Park	Tourist Area
Nam	4 351	21 740	1 346	759	61 038	7 260
Esc	46 886	52 009	21 966	0	3 624	0
Mo	20 027	29 545	78	0	14 136	0
AW	94 988	2 837	4 309	0	783	0
NK	6 159	112 235	3 572	0	10 021	0
CK	31 904	21 714	7 378	0	0	0
SK	68 198	715	1 569	0	0	0
NKo	86 585	11 809	14 672	0	1 153	0
SKo	11 044	0	0	23 011	4 646	0
Total	370 142	252 604	54 890	23 770	95 401	7260

Results

The estimated numbers of birds of each species per QDS are listed in full in Appendix 6. Overall estimates of total bird numbers for each species occurring within major river courses and in non-riverine areas are given in Table 12, while Table 13 shows the estimated numbers within each avi-vegetational zone, and Table 14 the estimated numbers within the four main protected land areas. Table 15 shows the estimated bird numbers within six classes of land tenure.

Extrapolating the predicted values across Waterberg Plateau Park was seen to be inadequate because of the unique nature of the topography in the park. The plateau is characterised by almost vertical slopes in some areas, elevating the park to an altitude approximately 200 m above the surrounding land. Whilst predicted values appeared to be a reasonable representation of bird density on the flat top of the plateau, the steep sides support many more birds than the surrounding areas, and these should be included in any population estimates of the park. Therefore in this case only, new density values were calculated from all transects undertaken on the slopes of the plateau. These values were then extrapolated across the total slope area, which was calculated by multiplying the plateau perimeter by the difference in height between the top and bottom of the plateau, taken to be an average of 200 m. Data in Table 12 - Table 15 take account of these recalculations.

Figure 16 Distribution of National Parks within Namibia.

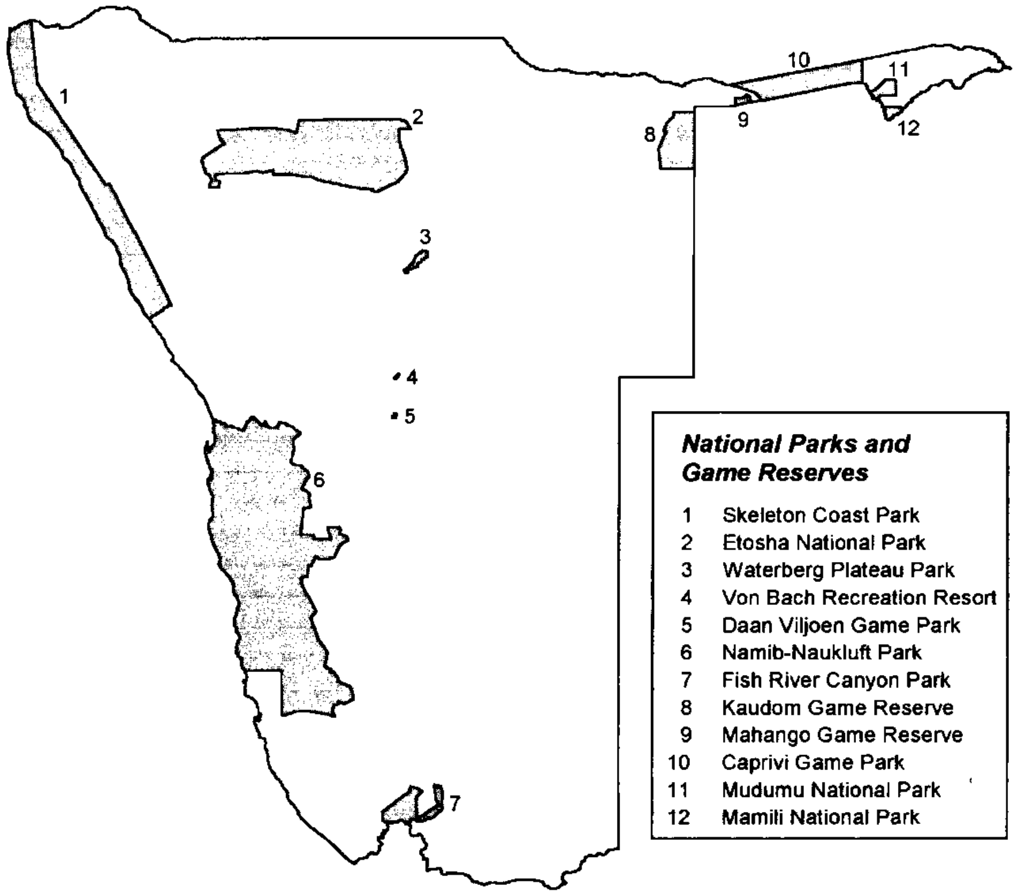


Figure 17 Distribution of land tenure within Namibia.

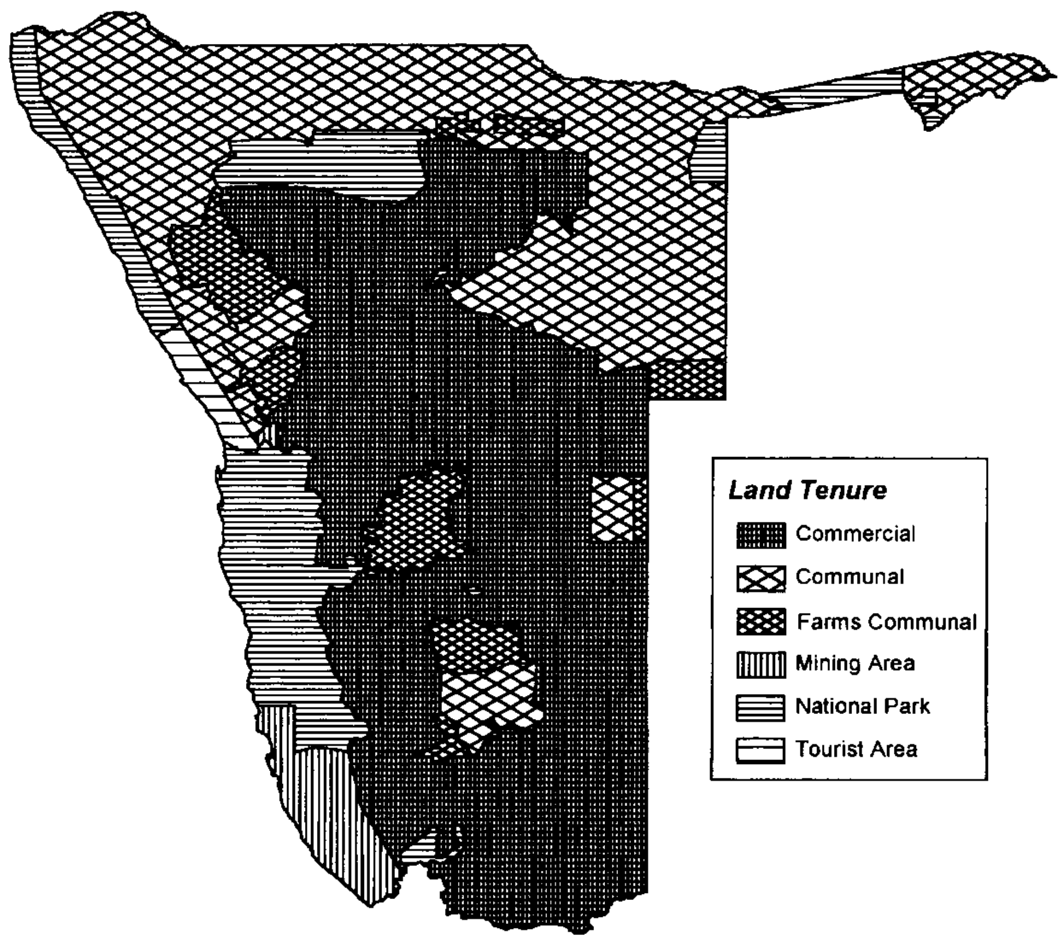


Table 12 Predicted numbers of birds (± error) within, and outside, major river courses in Namibia.

Species	River			Non-river			Total		
Hartlaub’s francolin	**0**	±	0	**26 527**	±	3 753	**26 527**	±	3 753
Rüppell’s korhaan	**0**	±	0	**99 860**	±	24 615	**99 860**	±	24 615
Rüppell’s parrot	**2 072**	±	334	**27 394**	±	16 058	**29 466**	±	16 392
Violet woodhoopoe	**1 848**	±	394	**0**	±	0	**1 848**	±	394
Monteiro’s hornbill	**2 219**	±	207	**337 346**	±	35 284	**339 565**	±	35 491
Carp’s black tit	**980**	±	395	**492 570**	±	83 575	**493 550**	±	83 970
Barecheeked babbler	**4 088**	±	1 442	**74 977**	±	24 456	**79 065**	±	25 898
Herero chat	**0**	±	0	**108 104**	±	3 606	**108 104**	±	3 606
Rockrunner	**0**	±	0	**96 464**	±	46 968	**96 464**	±	46 968
Whitetailed shrike	**3 843**	±	1 269	**1 497 186**	±	186 001	**1 501 029**	±	187 270

Table 13 Predicted numbers of birds (± error) within avi-vegetational zones in Namibia.

Species	Namib			Escarpment			Mopane			Arid Woodland		
Hartlaub's francolin	**0**	±	0	**8 360**	±	2 135	**9902**	±	688	**8 265**	±	930
Rüppell's korhaan	**42 519**	±	3 226	**57 340**	±	21 389	**0**	±	0	**0**	±	0
Rüppell's parrot	**0**	±	0	**10 473**	±	5 497	**12 294**	±	6 838	**6 794**	±	4 073
Violet woodhoopoe	**0**	±	0	**879**	±	262	**226**	±	33	**822**	±	118
Monteiro's hornbill	**0**	±	0	**92 570**	±	7 865	**71 563**	±	7 589	**175 529**	±	20 046
Carp's black tit	**0**	±	0	**176 230**	±	19 805	**105 270**	±	9 616	**212 106**	±	54 569
Barecheeked babbler	**0**	±	0	**5 358**	±	2 469	**65 157**	±	21 265	**8 932**	±	2 298
Herero chat	**0**	±	0	**108 104**	±	3 606	**0**	±	0	**0**	±	0
Rockrunner	**0**	±	0	**38 191**	±	9 974	**5 625**	±	3 987	**52 648**	±	33 006
Whitetailed shrike	**0**	±	0	**630 354**	±	33 459	**141 346**	±	77 605	**729 413**	±	76 261

Table 14 Predicted numbers of birds (± error) within protected areas in Namibia.

Species	Etosha National Park			Waterberg Plateau Park			Namib-Naukluft Park			Skeleton Coast Park			Total		
Park area (km²)	*22 270*			*405*			*49 768*			*16 390*			*88 833*		
Hartlaub's francolin	**1 603**	±	255	**429**	±	19	**162**	±	40	**0**	±	0	**2 194**	±	314
Rüppell's korhaan	**0**	±	0	**0**	±	0	**21 095**	±	1 936	**1 546**	±	499	**22 641**	±	2 435
Rüppell's parrot	**3 018**	±	1 374	**158**	±	114	**81**	±	46	**0**	±	0	**3 257**	±	1 534
Violet woodhoopoe †	**?**			**?**			**?**			**0**	±	0	**?**		
Monteiro's hornbill	**15 606**	±	3 492	**544**	±	751	**203**	±	47	**0**	±	0	**16 353**	±	4 290
Carp's black tit	**23 300**	±	2 825	**393**	±	305	**263**	±	83	**0**	±	0	**23 956**	±	3 213
Barecheeked babbler	**32 123**	±	7 891	**0**	±	0	**0**	±	0	**0**	±	0	**32 123**	±	7 891
Herero chat	**0**	±	0	**0**	±	0	**2 157**	±	77	**0**	±	0	**2 157**	±	77
Rockrunner	**2 356**	±	1 269	**4 373**	±	1742	**787**	±	210	**0**	±	0	**7 516**	±	3 221
Whitetailed shrike	**24 439**	±	9 928	**0**	±	0	**3 791**	±	660	**0**	±	0	**28 230**	±	10 588

† The predicted estimates for the violet woodhoopoe are for birds within major river courses. It is apparent that, although this species does occur outside river courses, it is typically within 50 or 60 km of a major river. Insufficient data were available to quantify bird numbers of this species outside river courses. As there are no major river courses within the boundaries of Waterberg Plateau Park a value of zero is predicted. Similarly, for Etosha and Namib-Naukluft unrealistically low numbers are predicted (2 and 1 birds respectively). During sampling, groups of violet woodhoopoe were observed within Waterberg (2 groups; 7 birds), and anecdotal evidence suggests that further groups are present. The major river courses within the QDS to the south of Waterberg are predicted to contain around 150 violet woodhoopoes and these are the likely source of the birds frequenting Waterberg. A similar situation is likely in Etosha National Park, where a number of groups are known. See text for further discussion.

Table 15 Predicted numbers of birds (± error) within different classes of land tenure in Namibia.

Species	Commercial			Communal			Farms communal			Mining areas			National parks			Tourist area		
Hartlaub's francolin	**19 846**	±	2 346	**3 113**	±	767	**1 374**	±	326	**0**	±	0	**2 194**	±	314	**0**	±	0
Rüppell's korhaan	**29 803**	±	8 442	**34 413**	±	8 945	**12 207**	±	4 555	**121**	±	22	**22 641**	±	2 435	**675**	±	218
Rüppell's parrot	**18 756**	±	11 080	**5 007**	±	2 771	**2 467**	±	1 118	**0**	±	0	**3 257**	±	1 534	**0**	±	0
Violet woodhoopoe	**1 090**	±	181	**450**	±	130	**330**	±	82	**0**	±	0	**?**			**0**	±	0
Monteiro's hornbill	**242 120**	±	25 054	**61 152**	±	4 757	**19 781**	±	1 999	**0**	±	0	**16 353**	±	4 290	**0**	±	0
Carp's black tit	**328 809**	±	65 149	**102 342**	±	10 559	**38 257**	±	5 263	**0**	±	0	**23 956**	±	3 213	**0**	±	0
Barecheeked babbler	**40 336**	±	14 036	**4 829**	±	3 222	**1 899**	±	787	**0**	±	0	**32 123**	±	7 891	**0**	±	0
Herero chat	**39 829**	±	1 201	**44 834**	±	1 559	**20 858**	±	757	**0**	±	0	**2 157**	±	77	**0**	±	0
Rockrunner	**60 759**	±	36 259	**18 846**	±	5 925	**9 315**	±	3 194	**0**	±	0	**7 516**	±	3 221	**0**	±	0
Whitetailed shrike	**981 846**	±	142 155	**354 341**	±	23 539	**135 991**	±	10 935	**0**	±	0	**28 230**	±	10 588	**0**	±	0

Discussion of results for each species

All estimated values presented refer to numbers of individual birds and it should be borne in mind that most of these species are typically found in small groups, rather than as individuals. Therefore an estimate of, for example, 3000 barecheeked babblers within a QDS suggests the presence of approximately 500 groups, assuming an average group size of around 6.0 birds (Table 3). This equates to a frequency of approximately 0.7 groups / km^2.

Hartlaub's francolin

Within its distribution, Hartlaub's francolin is generally restricted to koppies, inselbergs, gullies and scree slopes. However, there are currently no GIS maps available from which it is possible to identify these features reliably and distinguish them from less suitable areas across the francolin's range. Consequently, estimating population size for this species poses two problems:

- extrapolating densities across areas will produce locally inaccurate estimates due to small-scale variations in habitat availability; and

- on a larger scale, suitable francolin habitats are likely to be patchily distributed within the overall distribution of the species, leaving large areas of unsuitable habitat which should be excluded from calculations.

As a result, extrapolating predicted densities across all potentially suitable areas within their distribution (as defined by the environmental variables, and vegetation zones within which we observed them) almost certainly produces a gross over-estimate (168 432 ± 29 138: Figure 18). As it is currently impossible to define further the areas where they do and don't occur, we utilised the wealth of SABAP data collected over numerous years to derive estimates by extrapolating across only those QDS with positive SABAP records. These estimates are shown in Figure 19. They are likely to be underestimates as Hartlaub's francolin is generally poorly reported by SABAP: during our sampling we observed this species in eight squares not reported to contain it despite these squares having 10 or more record cards. This ratio suggests that it should occur in at least 15 more QDS than the 51 currently known to SABAP. Assuming that squares with fewer cards are more likely to under-report the presence of francolins, the actual number of extra QDS containing Hartlaub's francolin is likely to be substantially higher than 15.

The true population estimate therefore falls somewhere between the two values predicted but is most likely to be closer to the value derived utilising the SABAP distribution (Table 12) than from the overall extrapolation. Further data collection at a more detailed scale, including an assessment of where Hartlaub's francolins are found (and where they are not) would allow more precise definition of suitable and unsuitable habitats. This information could then be used in conjunction with very detailed maps, or other habitat data, to enable population estimates to be made at a more locally sensitive scale.

Rüppell's korhaan

The predicted estimates for Rüppell's korhaan are shown in Figure 20. Despite sampling within several QDS in the Nama Karoo zone, we observed Rüppell's korhaan in this zone only in the squares immediately adjacent to the Escarpment zone. All other korhaan observations within this vegetation zone were of the physically similar Karoo korhaan. The presence of Rüppell's korhaan is likely to reflect a transitional area of intermediate vegetation between these two zones, rather than the general suitability of the Nama Karoo. Therefore, rather than extrapolating density values across the whole of the Nama Karoo (where Rüppell's korhaan gives way to the Karoo korhaan), we assumed a density of zero for Rüppell's korhaan in this zone. The total population estimate for this species does not therefore include the relatively few individuals which do occur within the Nama Karoo, but this is likely to be insignificant in relation to the total.

Rüppell's parrot

<u>Within rivers</u>
The predicted estimates for Rüppell's parrot within rivers are shown in Figure 21. Although we observed Rüppell's parrot within the fringes of the Northern Kalahari vegetation zone (and it has been reported infrequently in this zone by SABAP), it appears that relatively little of this zone is suitable because of the absence of major rivers, and the distribution of this species is restricted to the ecotonal areas adjacent to more suitable vegetation zones. Rather than wrongly extrapolating density values across the whole of the Northern Kalahari we assumed a density of zero there. The numbers of Rüppell's parrot present in the east of the country may have been slightly underestimated as a result of this assumption.

<u>Outside rivers</u>
Rüppell's parrot is predominantly a riverine species; however, it does occur sporadically outside major river courses. The regression relationship derived for non-riverine individuals indicated an increasing density with altitude. However, because of the sporadic nature of this occurrence (probably related to particular food sources or local water points), extrapolating the values predicted by this relationship across the whole of their range is unjustified. The limited number of sightings outside river courses did not allow us to define adequately the limits of their occurrence in these areas. We therefore made use of SABAP data to define their distribution, and extrapolated the predicted density values across only those QDS with positive SABAP records. This prevented attributing density values of this species across large areas where it is unlikely to occur and, as it appears to be reasonably well reported by SABAP (unlike Hartlaub's francolin), should produce a credible estimate for non-riverine areas. The resulting estimates are shown in Figure 22.

Violet woodhoopoe

Violet woodhoopoes and redbilled woodhoopoes are currently considered to be two distinct species; however, there is some debate about the validity of this distinction. Mornè du Plessis (pers. comm.) considers that violet and Redbilled woodhoopoes cannot be distinguished in the field on the basis of their calls as commonly stated, suggesting that differences in calls are sex, rather than species, related. He considers that differences in size also cannot be used to distinguish specimens in the field, but that mantle colour may be the most useful field characteristic. Some groups which he has examined have 'consisted of individuals that would pass as redbilled woodhoopoes, as well as individuals that would pass as violet woodhoopoes'. During our own sampling we also found groups containing individuals making the cackling calls attributed to violet woodhoopoes together with individuals making the higher pitched calls attributed to redbilled woodhoopoes (Gibbon 1991). Where possible, our field identifications were based on the presence or absence of green iridescence on the mantle. The distribution map (Figure 23) should give some indication of the distribution of violet woodhoopoes (based on our interpretation of mantle colour and calls); however, genetic analysis is evidently needed to clarify the taxonomic status of these two 'species'.

All sightings of violet woodhoopoes reported to SABAP are within, or adjacent to, a QDS containing a major river, except for those reported within Etosha National park. This suggests that this species is largely restricted to areas within a threshold distance of a major river, perhaps as a result of limitations on their preferred food supply, or breeding requirements. It was not possible in this study to define the conditions in which they occur outside major river courses, and no estimate was made of the number of non-riverine individuals. The population estimate presented is likely to be an underestimate, although the number occurring outside major river courses is likely to be comparatively low.

Monteiro's hornbill and Carp's black tit

Data obtained from field samples and those supplied by SABAP suggest that both of these species occur widely within the three avi-vegetational zones in which they occur. The predicted density values were therefore extrapolated across the whole of these areas with no further exclusions (Figure 24 and Figure 25).

Barecheeked babbler

Our own sampling and SABAP records suggest that the distribution of the barecheeked babbler is restricted to areas north of the 21° line of latitude, except for the Ugab river near Brandberg. The ecological reasons for this are unclear but appear to be unrelated to general differences in vegetation, altitude or rainfall. No extrapolations were made south of this latitude except for the riverine areas around Brandberg.

<u>Within rivers</u>
Predicted estimates for babblers within major river courses are shown in Figure 26.

<u>Outside rivers</u>
Similarly to Rüppell's parrot, barecheeked babblers do occur sporadically outside major river courses but the data were insufficient to define exactly where. SABAP data were again used to identify those QDS where they are reported to occur and to limit the extrapolations to these areas (Figure 27). The apparently high number of barecheeked babblers in Etosha National Park, predominantly in the southern section, is questionable and may be the result of the poor data and extrapolation procedure used for non-riverine babblers. Further data collection in this section of the park would help to clarify their status there.

Herero chat

The Herero chat was observed in the Escarpment zone only and, despite adequate sampling within all altitude zones, never at altitudes above 1 800m. Therefore although the equation suggests an ever-increasing density with increasing altitude, a predicted value of zero was assumed for all areas over 1 800 m. Areas above 1 800 m in this vegetation zone generally represent the interface with the Mopane zone, and because they are relatively flat would tend to be unsuitable for Herero chats. Additionally, as no Herero chats were observed in areas receiving over 300 mm of annual rainfall, we restricted the predicted distribution of this species to areas with less than 300 mm rainfall (Figure 28).

Rockrunner

Similarly to Hartlaub's francolin, the rockrunner has relatively specific niche requirements, inhabiting rocky slopes and outcrops with at least some grass cover. However, our sampling suggests that, in contrast to Hartlaub's francolin, the rockrunner is generally widespread across its area of distribution. We suggest that gaps in the SABAP data for this species, and indeed for Herero chat, reflect the cryptic nature of these birds and the ease with which these birds are overlooked if alarm calls and songs are not identified. Our predicted values for this species (Figure 29) therefore provide average estimates of abundance across areas of potentially suitable habitat. As with Hartlaub's francolin, estimates are likely to be inaccurate at a local level because of small-scale variation in the availability of suitable habitat, but should provide a useful estimate at the resolution of QDS.

Whitetailed shrike

Whitetailed shrike is the most widespread and abundant of the endemics, occurring across a wide area and range of habitats. They appear to be limited by rainfall in the east: no observations were made in areas with more than 430 mm annual rainfall and these areas were excluded from extrapolations. Figure 30 shows the predicted values for this species.

Figure 18 Predicted bird numbers: Hartlaub's francolin.

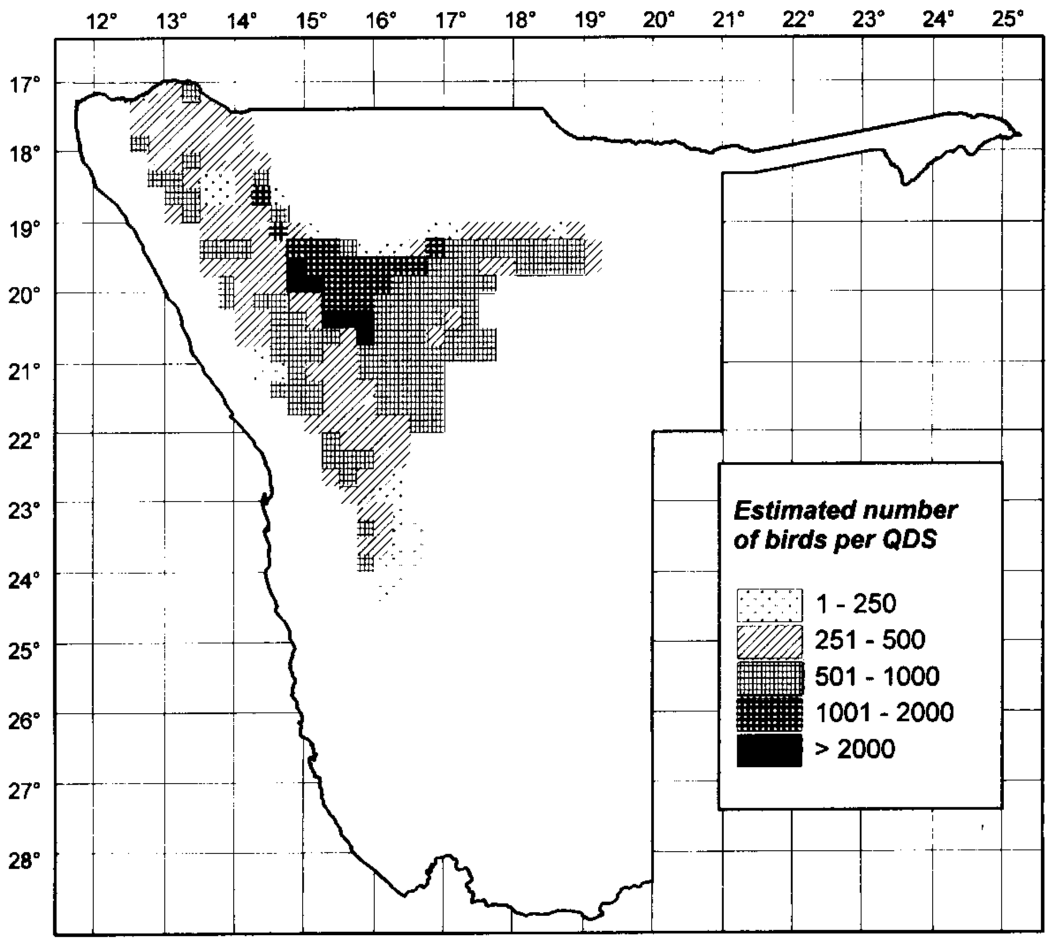


Figure 19 Predicted bird numbers: Hartlaub's francolin (extrapolated across only those QDS with positive SABAP records).

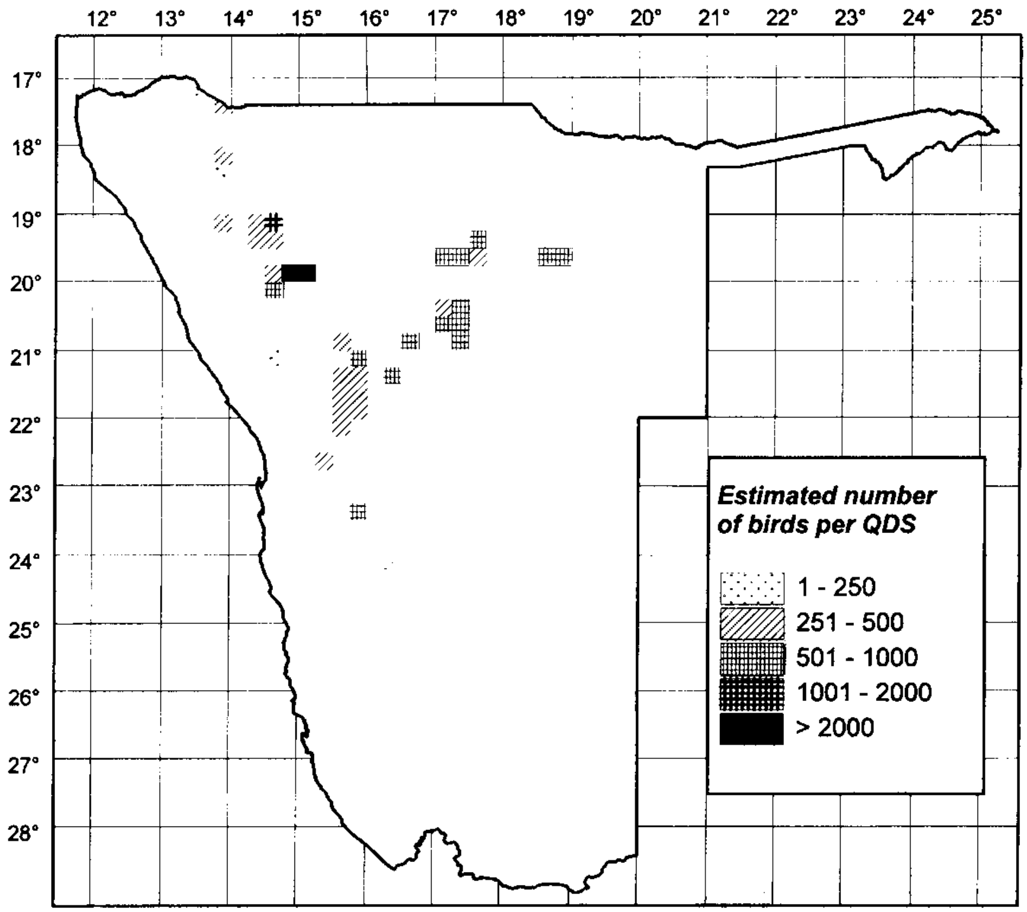


Figure 20 Predicted bird numbers: Rüppell's korhaan.

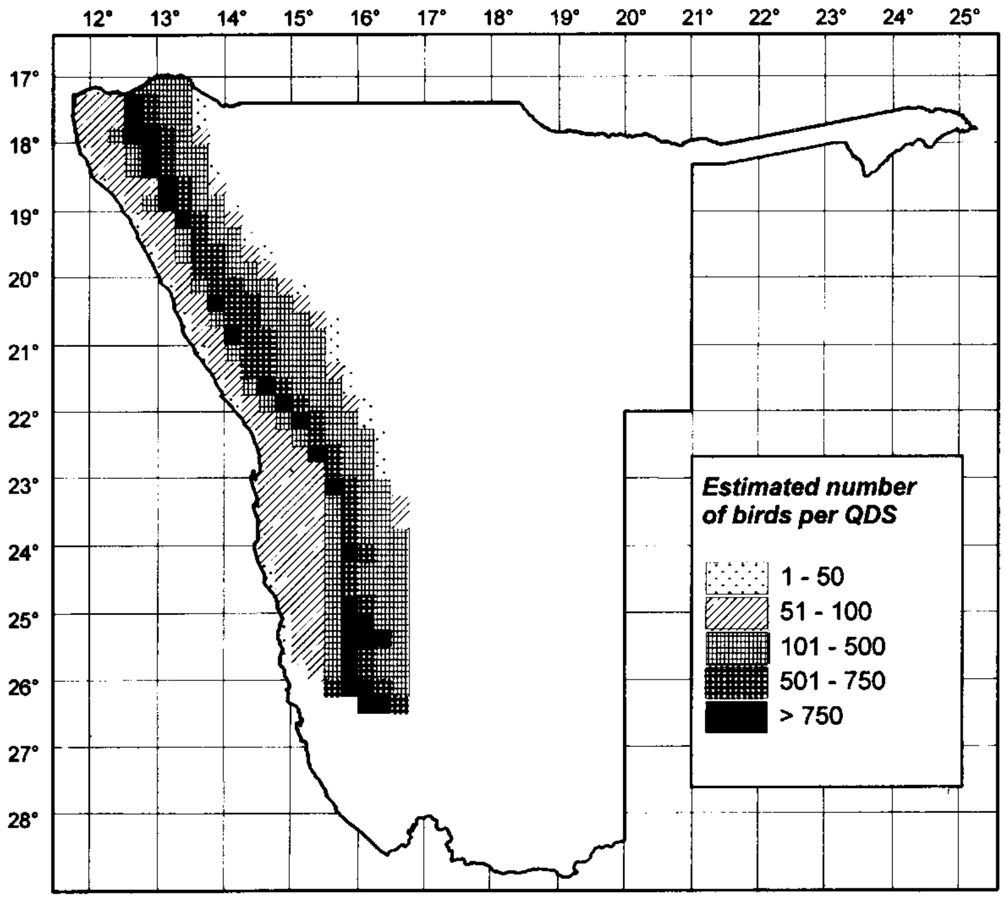


Figure 21 Predicted bird numbers within major river courses: Rüppell's parrot.

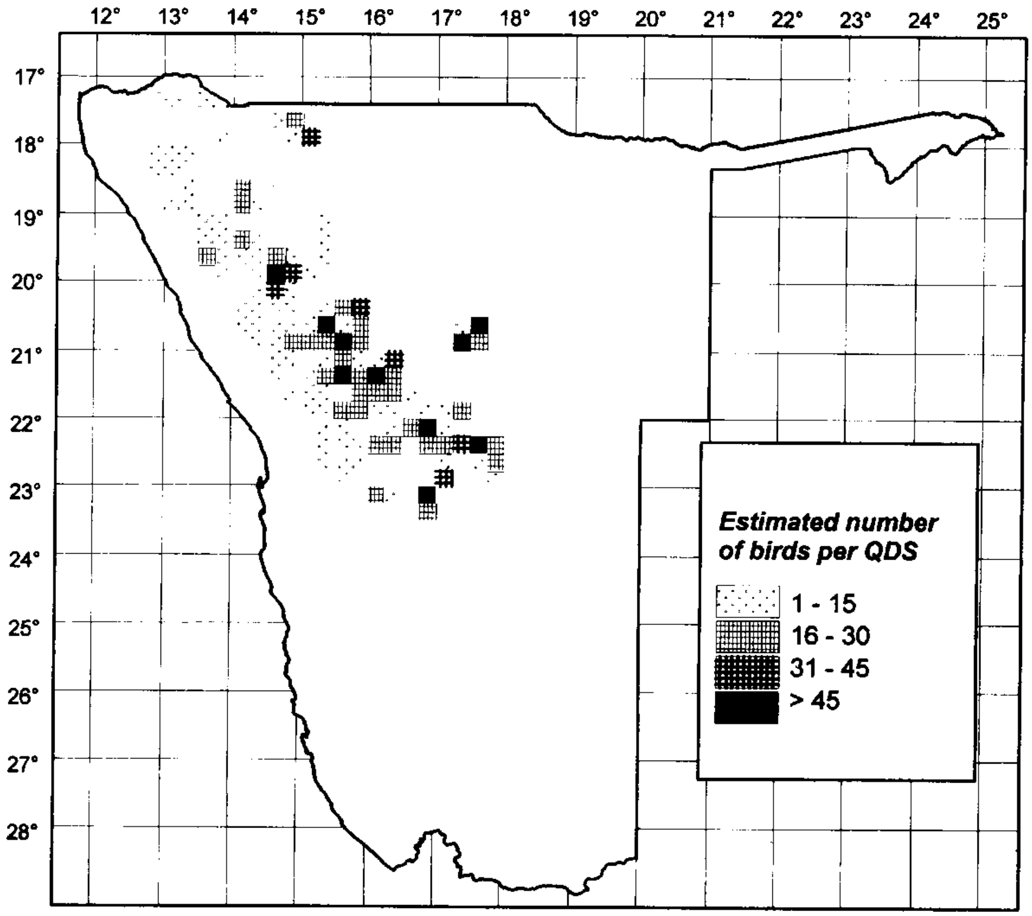


Figure 22 Predicted bird numbers outside major river courses: Rüppell's parrot.

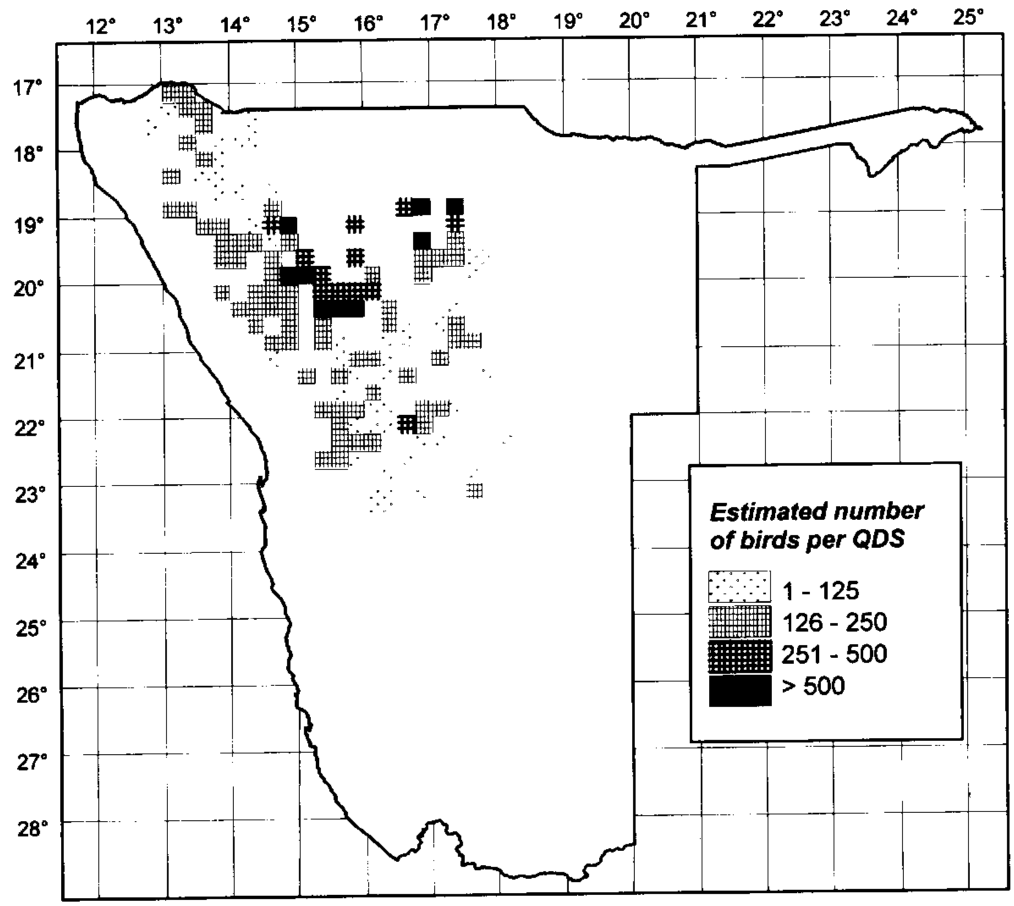


Figure 23 Predicted bird numbers: violet woodhoopoe.

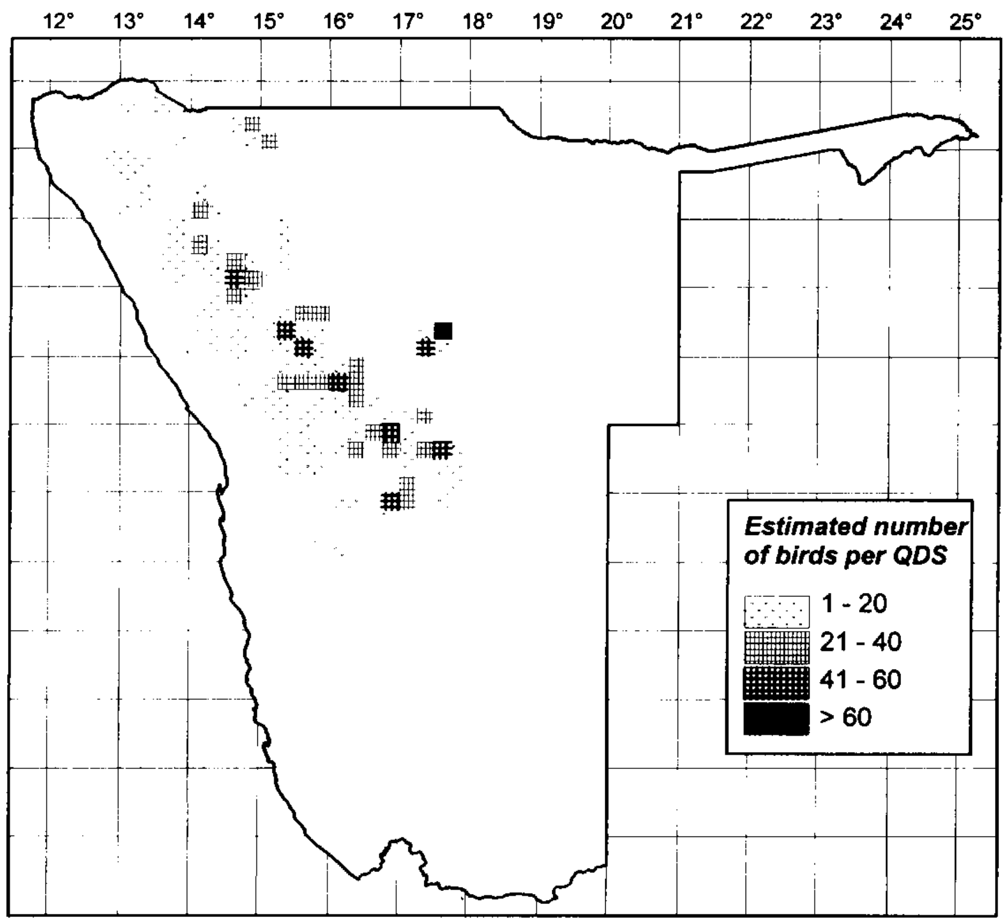


Figure 24 Predicted bird numbers: Monteiro's hornbill.

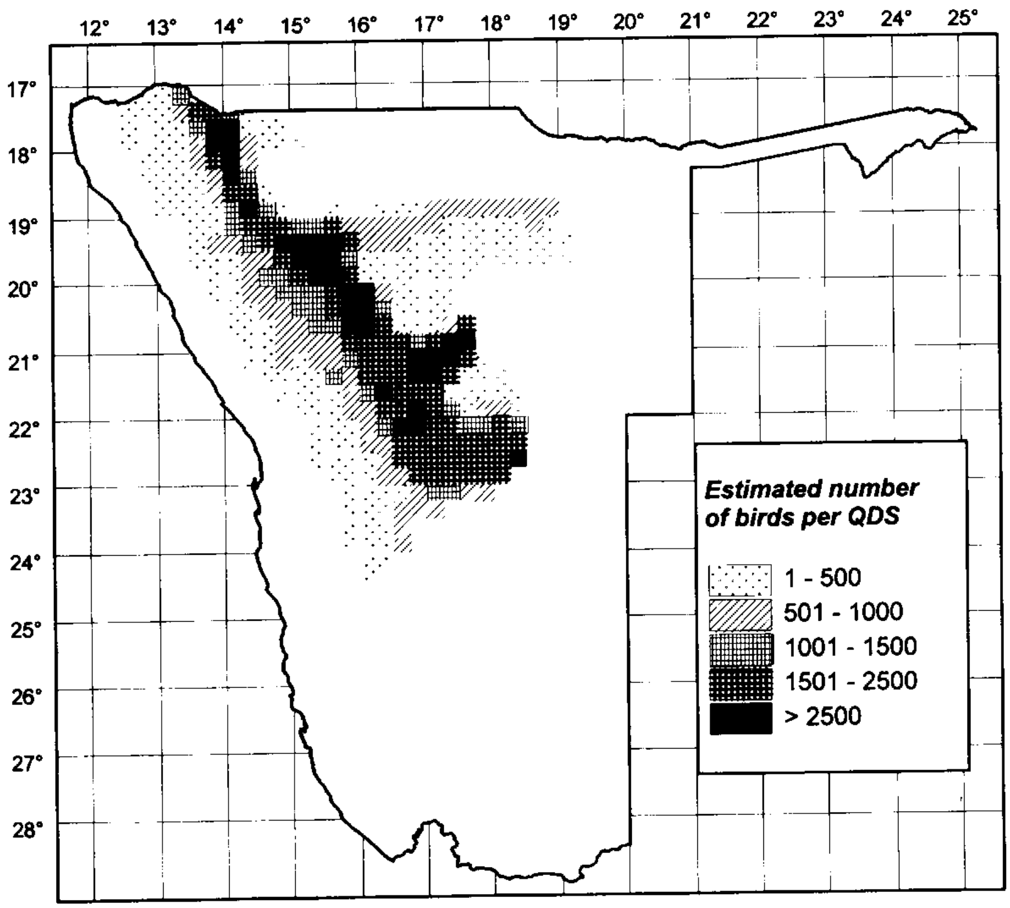


Figure 25 Predicted bird numbers: Carp's black tit.

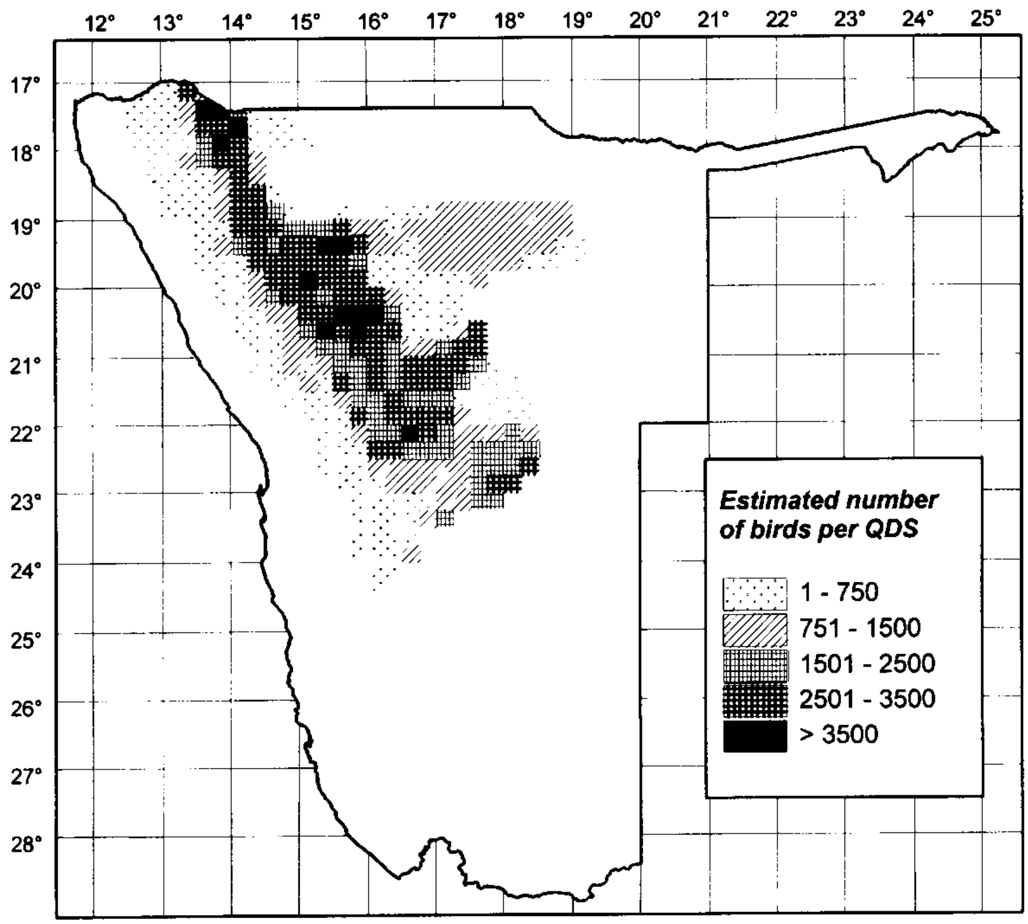


Figure 26 Predicted bird numbers within major river courses: barecheeked babbler.

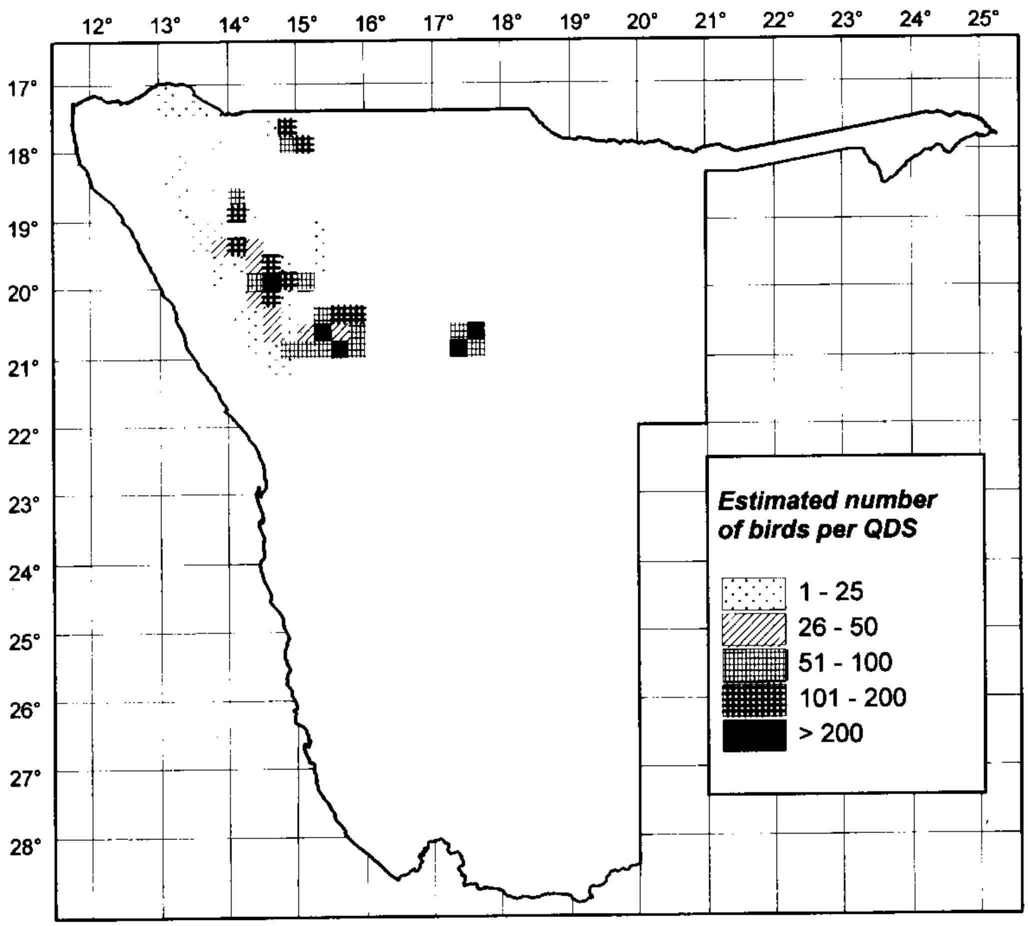


Figure 27 Predicted bird numbers outside major river courses: barecheeked babbler.

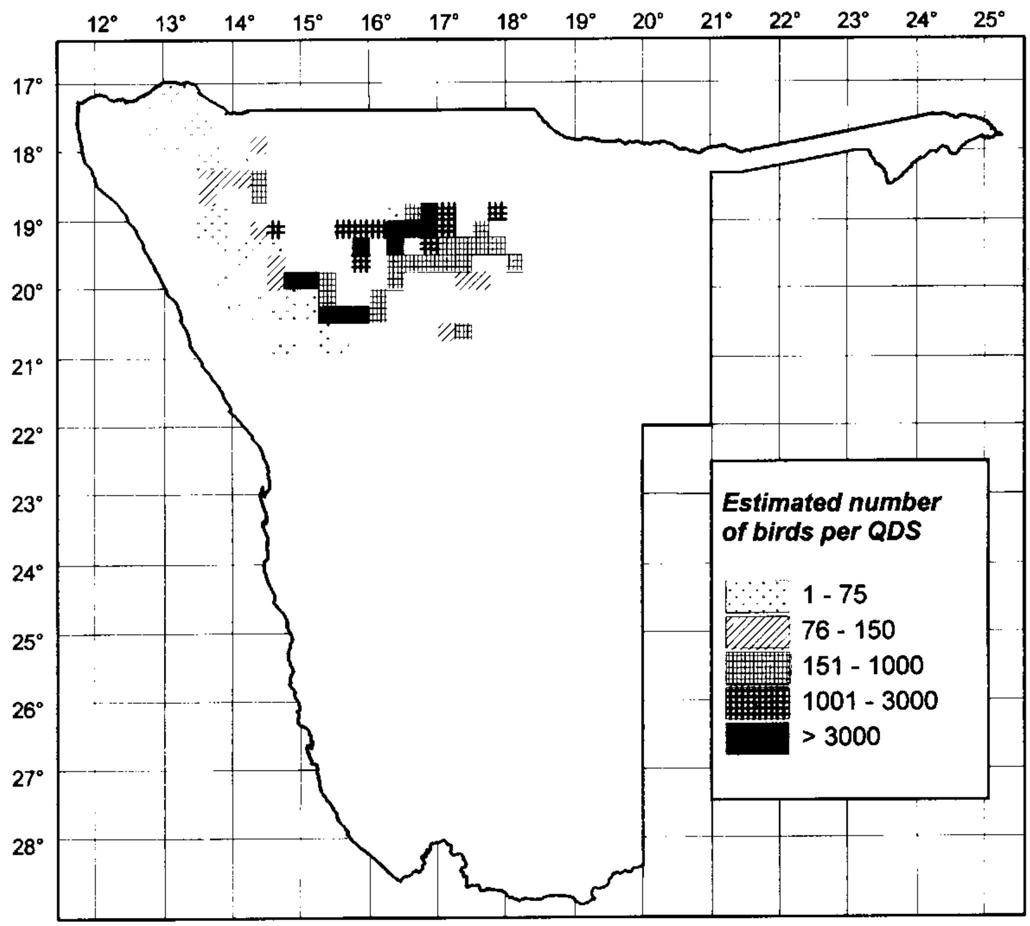


Figure 28 Predicted bird numbers: Herero chat.

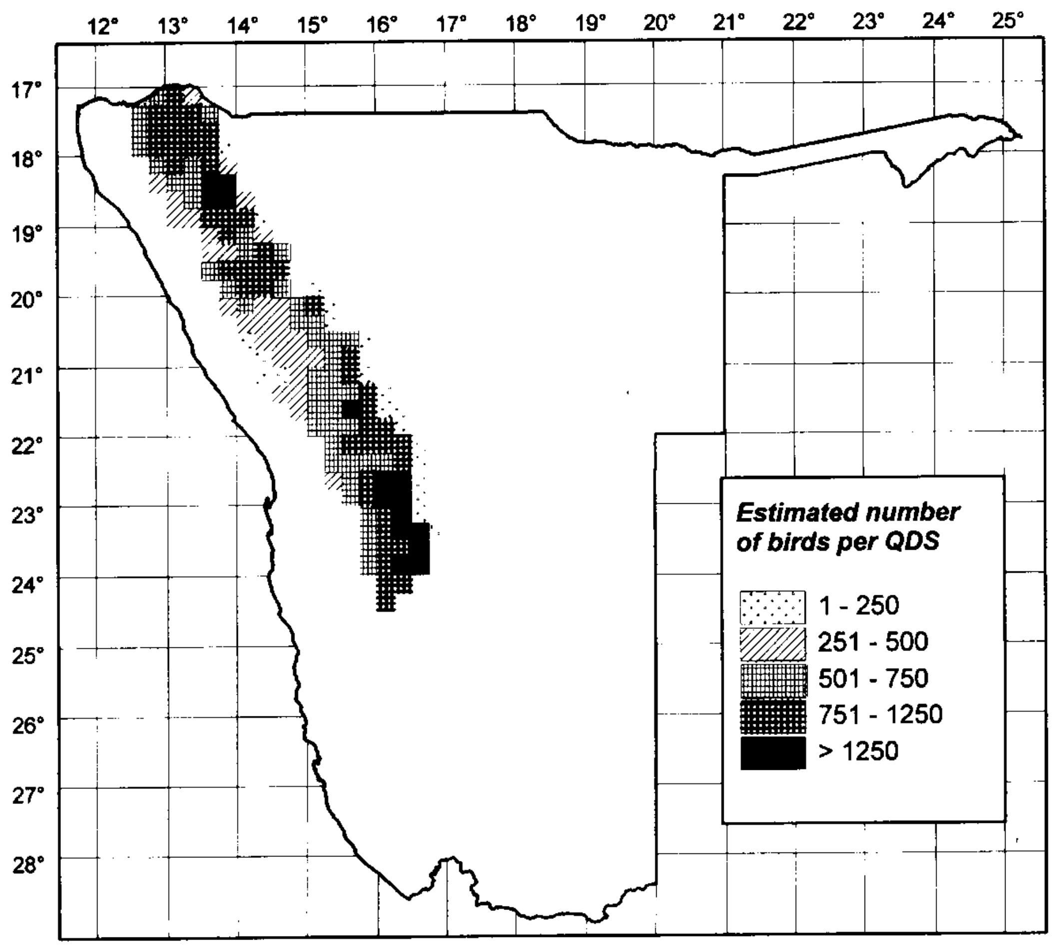


Figure 29 Predicted bird numbers: rockrunner.

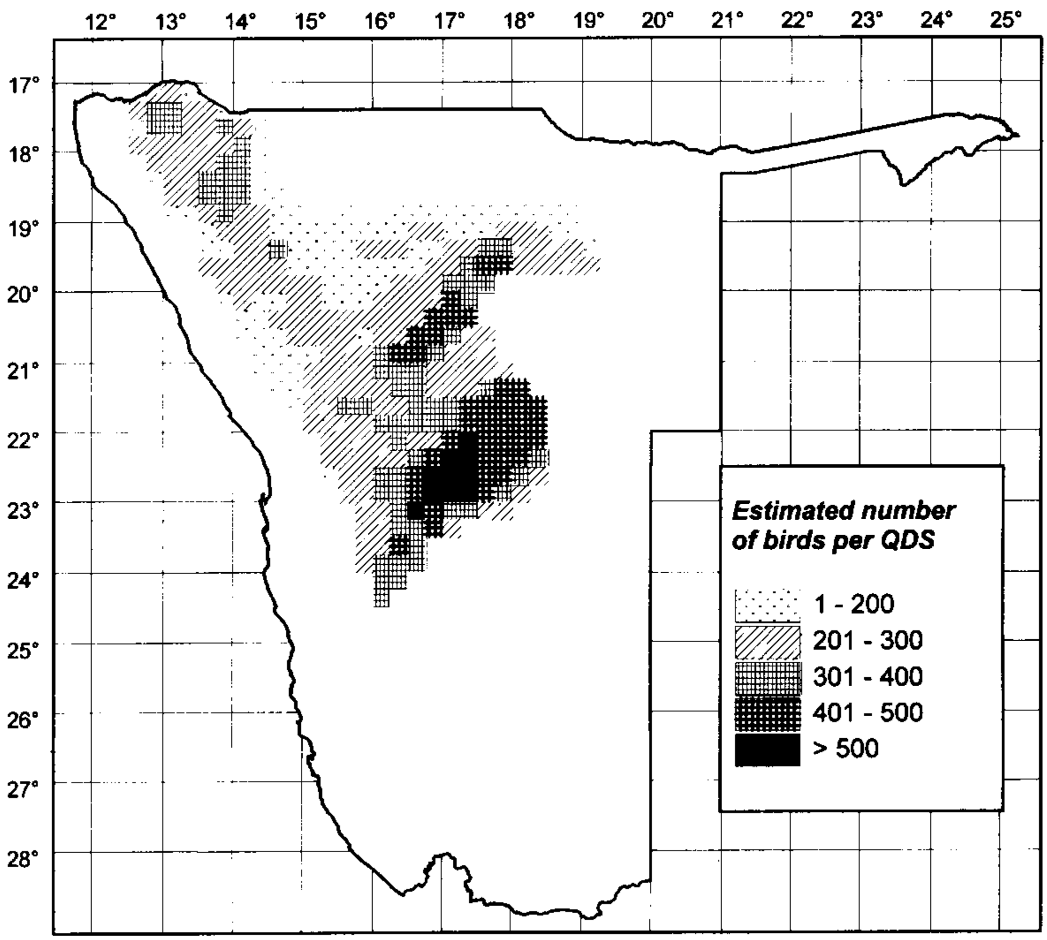
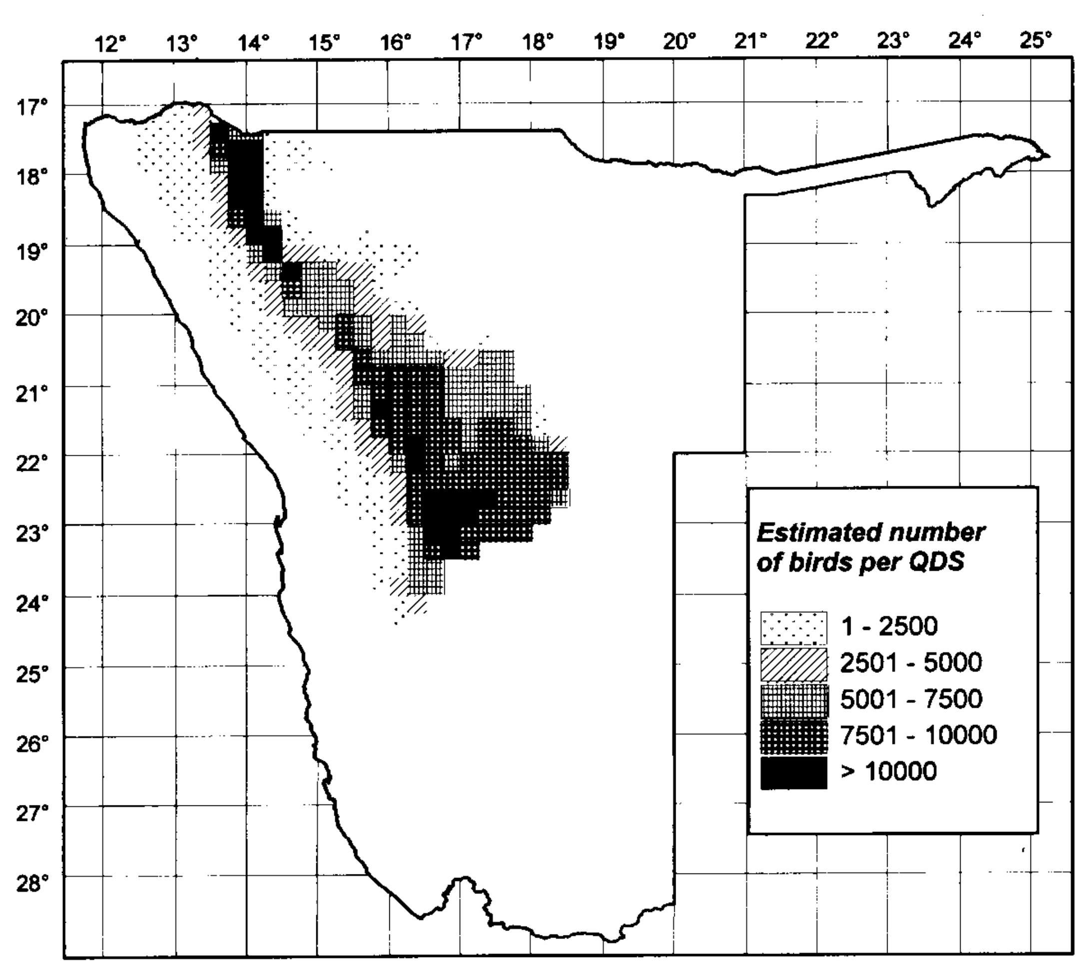


Figure 30 Predicted bird numbers: whitetailed shrike.



General discussion of results and the limitations of the extrapolation approach

Extrapolation of density estimates across all areas

For species which occupy a specific niche within their range, a more precise method for defining their habitat requirements would reduce the effect of error introduced by extrapolating across all areas. For Hartlaub's francolin, for example, line transects typically included areas which were both suitable (such as inselbergs and scree slopes) and unsuitable (flat areas), without distinguishing between them. The density values are thus derived from an average. The extrapolation of these values across large areas assumes even distribution of birds, when clearly there is local variation dependent on the presence of suitable habitat. The use of SABAP records to define the particular areas within the birds' distributions which are known to support the species is an attempt to refine the population estimates.

Use of appropriate maps

A further consideration in this method is the accuracy and reliability of the maps used. Ideally the maps should reflect the environmental situation at the time of sampling. For variables such as vegetation and altitude which are constant over time this is not a problem, but variables such as rainfall which change from year to year, may influence the distribution and density of birds at any particular time. The rainfall map used represents the average rainfall over a 10 year period, and thus provides a relatively crude representation of rainfall for the year of sampling. For species which are likely to follow variations in rainfall on a yearly basis, this may reduce the value of rainfall as a predictive variable. Using a map depicting rainfall over the year during which we sampled may have resulted in stronger relationships between density and rainfall; however, this was not readily available in digital form. The vegetation coverage used is recognised by Allan *et al* to be fairly crude and inaccurate in places and, in its present form, denotes only major divisions in vegetation types. As all the species considered here were found almost entirely within four vegetation zones, a finer scale of vegetation classification within this area would substantially enhance the accuracy of density estimates.

Use of GIS mapping techniques which take account of the three dimensional nature of topography could further increase the accuracy of estimated land areas in undulating regions. The benefits of this approach would only be realised with the use of a detailed digital terrain map and would perhaps be best suited to small scale studies using very detailed bird density information.

Reliability of extrapolated values

One way to check the reliability of the density estimates would be to undertake comprehensive field counts ('ground-truthing') in a number of relatively small areas to compare with the predicted values. It must be recognised, however, that the estimates calculated are only as sensitive as the scale of the unique combinations of environmental variables allows. For example, the total area of the Mopane vegetation zone between 900 m and 1 200 m in altitude, and between 300 and 310 mm of rainfall is 544 km^2. The estimates derived therefore include one predicted value for this entire area and do not take account of more fine scale variations in bird numbers. To test the reliability of predictions, several counts would need to be made within a target area to provide an average estimate for comparison with the predicted values.

Comparison of population estimates with previous estimates

Tentative population estimates were made previously for four of the species by using the relationship between SABAP reporting rate and bird abundance in QDS (Robertson *et al* 1995). These were: whitetailed shrike 359 347; Monteiro's hornbill 110 312; Rüppell's parrot 9 700; rockrunner 13 489. The problems associated with making extrapolations across a large number of QDS with very limited atlas data were recognised and emphasised in this work. As a consequence of these problems, the estimates in Table 12 are much higher than those listed above. The main limitations to the use of atlas data in deriving these initial estimates are detailed below:

1) Because of time limitations of the previous study a number of people kindly agreed to undertake some sampling on our behalf. This allowed the number of areas sampled to be increased, and substantially increased the quantity of data collected. However, it was evident that the effects of observer variability were large in some cases and likely to have had a large effect on some of the calculated density values, resulting in significant underestimates of bird numbers.

2) As almost half of all QDS in Namibia have five or fewer reporting cards (Table 16), it is to be expected that many gaps appear in SABAP distribution maps, particularly for the more cryptic species such as rockrunner, Herero chat and Hartlaub's francolin. This is likely to be the main reason for differences between the two sets of predictions, as estimates in Table 12 extrapolate over a high proportion of QDS additional to those recorded by SABAP. While fewer gaps appear for whitetailed shrike and Monteiro's hornbill, these are among the most numerous of the 10 species and many QDS contain several thousand birds of these species. Therefore the omission of a relatively low number of QDS from calculations will have a large impact on the total estimates.

Table 16 Number of SABAP cards per quarter-degree square.

Number of cards	**Quarter-degree squares (QDS)**		
	Number	% of total	Cumulative total (%)
0	40	3.2	3.2
1 - 5	551	44.4	47.6
6 - 10	236	19.0	66.6
11 - 20	199	16.0	82.6
21 - 30	72	5.8	88.4
31 - 40	33	2.7	91.1
41 - 50	23	1.9	93.0
51 - 100	59	4.8	97.8
101 - 150	14	1.1	98.9
151 - 200	6	0.5	99.4
> 200	8	0.6	100.0

3) As a result of the high numbers of QDS with low numbers of cards, reporting rates are inevitably relatively insensitive and repetitive for many squares, resulting in a limited set of

reporting rate values being substituted into the regression equations. Additionally, poorly covered squares tend to be in remote, inaccessible areas which are largely uninhabited. Records from these squares are often derived from short visits by birders to limited areas, and are likely consistently to under-report species. For a square with few cards the difference between one sighting and two sightings of a species substantially alters the reporting rate.

4) The relationships between abundance and reporting rates were calculated using log-transformed abundance values. Because of the problems associated with reporting rates from QDS with only one or two cards, the estimates presented in Robertson *et al* (1995) were calculated only from QDS with three or more cards. This excluded around 50 squares within the distribution of whitetailed shrike and Monteiro's hornbill. Additionally, for more abundant species, the effect of under-reporting will be magnified in the final estimate as a result of the log transformation: a small difference in reporting rate can produce a large difference in the abundance estimate obtained. This effect, in addition to differences in the areas included in the extrapolation process (considered above), may explain the greater differences in estimates for whitetailed shrike compared to Monteiro's hornbill.

Using the relationship between reporting rate and abundance for those squares sampled during the current study to estimate population numbers, in the same way as previously, produced the following estimates: whitetailed shrike 583 381; Monteiro's hornbill 105 342; rockrunner 14 225. The equations used are presented in Table 17 (page 75). These values are close to the previous ones listed above, providing encouraging support for the consistency of the methods. However, it is evident that the use of atlas data for abundance predictions will result in population estimates which are too low.

Because of the limitations of using reporting rate to estimate abundance, we suggest that the estimates of population size based on environmental parameters, as presented here, are much more likely to approach the true values than those derived using atlas data.

Chapter 4: Conservation management implications

Are the populations of endemics sustainable?

Nationally

A number of factors will influence the minimum number of individuals of any species required to ensure genetic sustainability and viability. Populations are at risk of extinction as a result of perturbations such as:

- variation in birth rates and death rates;
- decreasing habitat quantity and quality;
- inbreeding and loss of selectable variation; and
- removal of something essential or introduction of something lethal.

The minimum population size required to withstand these threats will vary from species to species. A minimum effective population size for any species is suggested to be of the order of 500 individuals (Frankel and Soulé 1981), which translates into a much larger number of breeding adults in real populations. The results presented in Chapter 3 suggest that none of the endemics is currently likely to be at or below this level nationally, with the possible exception of the violet woodhoopoe

Within National Parks

It is apparent that the National Parks within Namibia do not coincide with the areas containing high numbers of endemics and may not generally contain viable numbers of many of these species (Table 14). A large area of the distribution of Rüppell's korhaan falls within the Namib-Naukluft Park, suggesting that viable numbers of this species are adequately protected. Situated largely within the Namib avi-vegetational zone, this park is of limited value for the other species although it does contain the only Herero chats currently protected. The large size of Etosha National Park ensures that it contains parts of the distributions of many of the endemics, and includes reasonable numbers of at least three species. However, Etosha is situated too far north and east to include the core areas within the distribution of most of the endemics, and thus includes sub-optimal areas of comparatively low bird density for these species. The rocky slopes around Waterberg Plateau Park support relatively high numbers of rockrunner (and Hartlaub's francolin), and a number of the other endemics are found there. However, the small size of this park makes it unlikely to be capable of supporting viable numbers of most of these species. The Skeleton Coast Park, located entirely within the Namib zone, is outwith the distributions of all species except Rüppell's korhaan, which is present at very low density.

In conclusion, although all of the 10 species considered are represented within the existing parks network, they are not all present in sustainable numbers. If there is large scale environmental change outside the parks system some species may be at risk from the threats listed above. Designating further protected areas could ensure the protection of viable numbers of these species.

Identification of the key areas for the endemic birds

Before considering the alternatives of either extending an existing protected area or designating a new one(s), an assessment is needed of where the key areas are for the species concerned.

The distribution maps for each of the endemic species presented in Chapter 3 (Figure 18 - Figure 30) provide information on the approximate numbers of birds estimated to occur in each QDS. As expected, several species show similar patterns of optimal and sub-optimal areas across their distributions, and it is apparent that the escarpment is generally a good region for endemic birds. It is, however, difficult to assess the degree of coincidence of these areas for different species, and to compare areas objectively. The most simplistic way to examine the relative importance of a particular QDS for a selected group of species is to determine the number of those species present within that square (species richness). However, this takes no account of relative abundance and gives the same importance to a QDS containing all species but with most at a rare or vagrant level, as to a QDS containing all species in large numbers. When considering the designation of a new conservation area it is obviously preferable to give priority to areas containing proportionally high numbers of most, or all, of the key species identified. A more appropriate approach, therefore, is to use an index of diversity which is based on both species occurrence and abundance.

Calculation of a diversity index

A slightly modified Shannon index (H*) was calculated (Magurran 1988) to produce the following index of species diversity for each QDS, based on both the occurrence and relative abundance of the species occurring:

$$H^* = - \Sigma \ p_i \ \ln \ p_i$$

p_i was estimated as n_i / N, where n_i is the proportion of the total population of the *i*th species (rather than absolute abundance) and $N = \sum n_i$. (For the purposes of this analysis, Hartlaub's francolin distribution was taken to be as shown in Figure 18). We used proportions rather than absolute abundance values to reduce the effects of order of magnitude differences in bird density between species. This index provides a measure of 'evenness' in the proportion of species occurring within squares. A QDS with few species, or uneven proportions of species, will receive a relatively low index value whilst those containing most or all species at similar proportions will receive a relatively high value.

By applying the index equation, every QDS in Namibia predicted to contain any of the endemic species was assigned an index value. These values were then ranked to produce a hierarchy of diversity. Figure 31 shows the modified Shannon index values for each QDS, based on the predicted numbers of all 10 species, presented as the top 5 % of record-containing squares, next best 5 % and so on. 'Hotspots' were defined as the top 5 % of QDS which were predicted to contain any of the endemic species, ranked using the index values. Figure 32 shows the modified Shannon index values recalculated after excluding Rüppell's korhaan, the only species with a significantly different distribution from the other endemics.

Figure 31 Shannon index values calculated using all 10 endemic species.

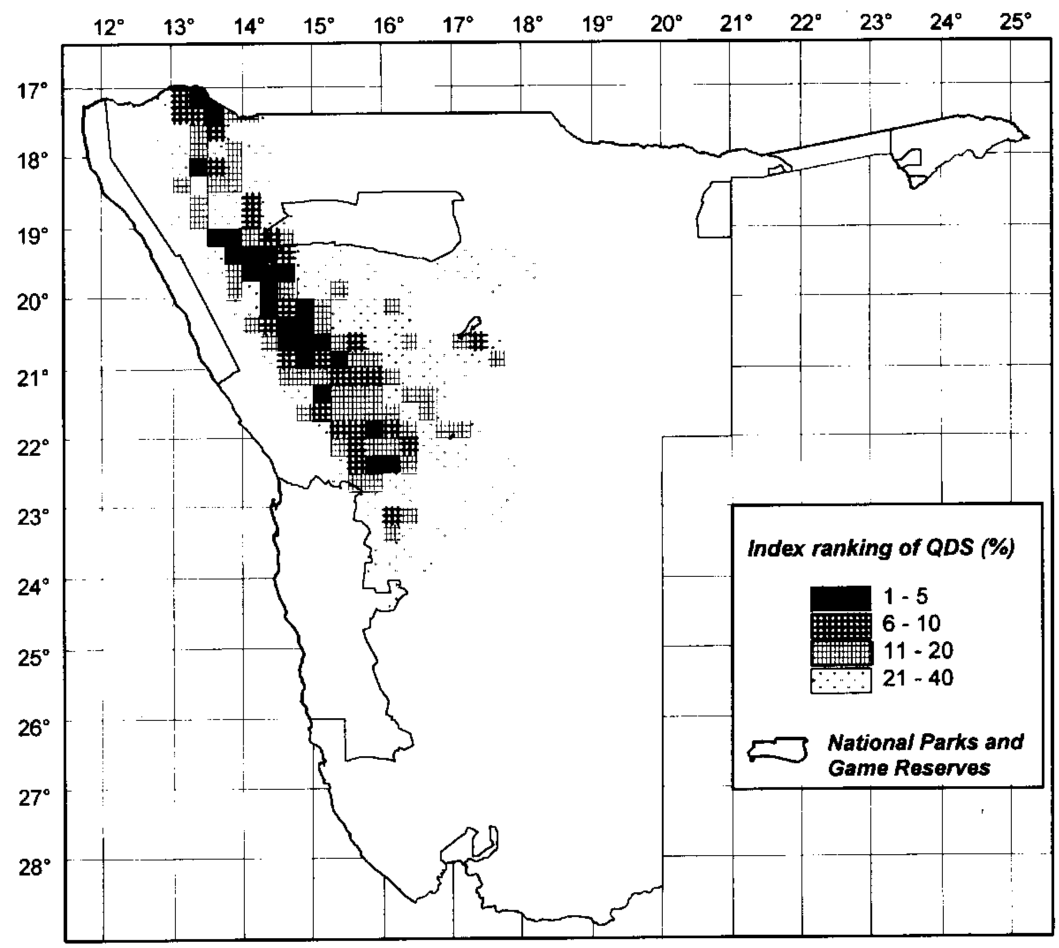
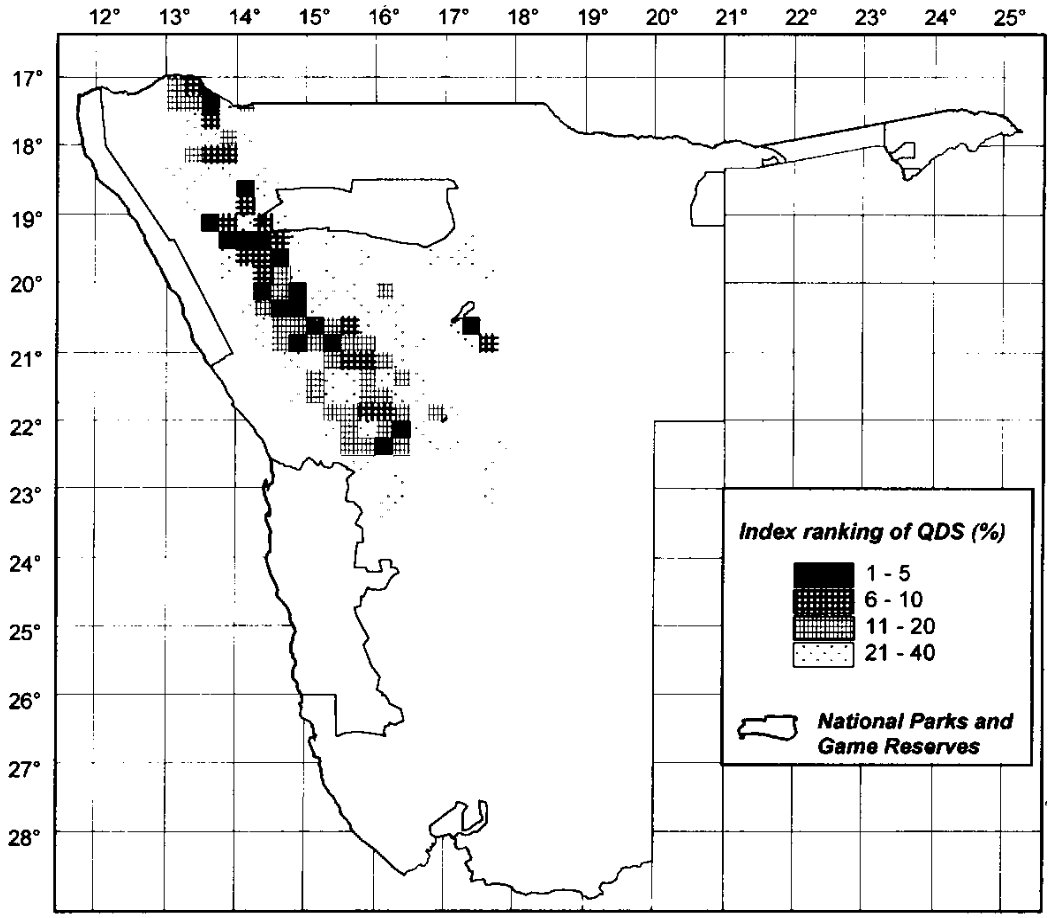


Figure 32 Shannon index values calculated excluding Rüppell's korhaan.



Locations of hotspots of endemism

When all 10 species are included in the modified Shannon index, all hotspots are located within the escarpment avi-vegetational zone (Figure 31), highlighting the general importance of this zone for the endemics. The region containing the hotspots stretches from the Cunene river to the Swakop river near the eastern edge of the Namib-Naukluft park. There is a high concentration of hotspots around the areas south and west of Khorixas, extending northwards to Sesfontein. The main concentration of hotspots falls between Sesfontein and Otjihorongo. The remaining hotspot squares are more scattered, occurring where major rivers cross the escarpment. These squares include areas around Okambahe (Omaruru river), Karibib (Kahn), the Zebra mountains (Cunene) and to the west of Opuwo (Hoarusib).

The three endemic species not considered in this study (Dune Lark, Gray's Lark and Damara Tern) are found almost exclusively within the Namib avi-vegetational zone. Similarly, of the 10 endemic species under consideration, Rüppell's korhaan is the only species which inhabits the true desert, with a significant proportion of its distribution within the Namib zone. These four species have sufficiently different habitat requirements from the other nine species to justify grouping them separately. Moreover, as the four species are already relatively well represented within existing protected areas by virtue of their distributions, we recalculated the diversity index using only the nine species. This second analysis emphasises the importance to these species of the central section of the escarpment zone (Figure 32), although many hotspots are common to both analyses. Again, the main concentration of hotspots falls between Sesfontein and Otjihorongo; other important areas include the Swakop river near Otjimbingwe, and the Waterberg Plateau Park within the Arid Woodland zone. The majority of hotspot QDS are within communally owned land ('Communal' and 'Farms communal'), thus communal land, despite being potentially more degraded than commercially farmed land, appears favourable for these species.

Appendix 7 lists the top 40 % of QDS in order of their index rank, based on the presence and abundance of nine endemic species, and includes information on the predicted number of endemic species in each QDS.

Implications for future conservation actions

Although the escarpment vegetation zone is the most species-rich with respect to the endemic birds considered in this study, it is apparent from Figure 31 and Figure 32 that very little of this zone is currently included within the National Parks system (see also Table 11). The area included is in the relatively species-poor southern section of the escarpment, along the eastern edge of the Namib-Naukluft park. Designating a new conservation area within the escarpment zone, including some of the hotspot QDS identified could significantly enhance the protection status of endemic birds, especially those such as the Herero chat which are currently poorly represented within the existing parks network.

The majority of the hotspot QDS are sited within the central core of the escarpment zone (i.e. not bordering other avi-vegetational zones), and any new conservation area should preferably be sited within this core area. Harrison and Martinez (1995) identify a number of reasons for prioritising core areas, rather than transitional areas, for conservation:

- core areas are most likely to have the environmental characteristics which define the biological characteristics of the zone and are therefore most likely to maintain gene pools peculiar to that biome;

- population density decreases towards the edge of a species range as a result of both habitat deterioration and competition. Species are conserved more effectively in optimal habitat where densities are relatively high; and

- core areas are relatively buffered against future climatic changes which may cause shifts in the positions of boundaries.

The optimal areas identified fall within communal, farmed communal and commercial land. As the designation of a new protected area would depend to a large extent on land ownership, this introduces a degree of flexibility in the selection of a suitable site.

Chapter 5: Recommendations for future monitoring and research

The steady increase in pressure imposed on the natural resources of Namibia by an increasing human population will inevitably result in some modification of habitats and ecosystems. Not only will this potentially influence the 10 bird species considered here, but may also have important consequences for many species across a range of taxa. The ability to monitor and assess changes in bird numbers over time in different areas will provide important insights into impacts of changing land management on these populations. While this information would enhance the conservation of these species, there may also be important implications for other species existing under similar ecological constraints.

Undertaking extensive field surveys of target species is, however, both time consuming and costly. Having a simple and efficient means of monitoring change would allow for the rapid assessment of the current status of these species. This is perhaps one of the many important roles atlas data can play in conservation.

The potential for future monitoring of the endemic birds using atlas data

Amongst other information, the SABAP database contains data on the relative abundance of all bird species within each QDS in southern Africa. Establishing a relationship between reporting rate and actual abundance could theoretically provide a relatively simple means of both estimating total population size and undertaking long-term monitoring and assessment of bird numbers and distributions using simple atlas-type data.

The most important consideration, however, is whether or not estimates derived from these relationships are realistic. The large differences between total population estimates determined using environmental correlates (in Chapter 3) and those derived using SABAP data (Robertson *et al* 1995) suggest that this approach is unsuitable for predicting accurate total population sizes. The limitations identified in Chapter 3 result in estimates which are almost certainly too low, because of gaps in the SABAP data and the convergence effect of low coverage on the reporting rate. While these factors may limit the use of SABAP data for deriving total estimates, the validity of the actual relationships obtained should not be compromised: the accuracy of estimates derived from the equations will merely depend on the integrity of the atlas data used. In the present study, and previously, the selection of sample QDS used was based on a minimum card number and only QDS with at least 10 record cards were used in the regression analysis. In addition, squares were selected to provide a range of reporting rates for each species. We therefore suggest that statistically significant relationships between reporting rate and abundance remain useful for the prediction of bird numbers over particular QDS where SABAP data are sufficiently robust to apply the equation i.e. for squares with large numbers of record cards. These relationships could thereby provide a means of monitoring changes in bird numbers for particular QDS. For example, if atlas data were collected in the future for a subset of QDS, the new reporting rates could be substituted into the appropriate equation to obtain a revised estimate of bird numbers in those QDS for a particular species. If this exercise was undertaken over a random sample of squares, an indication of the actual magnitude of change in bird numbers could be obtained. Interpretation of results from this exercise would need to be treated with some caution, however, as some knowledge of natural fluctuations in bird numbers would be required before a valid assessment of change could be made.

Deriving relationships between reporting rate and bird abundance

Following the same methodology used previously, predicted abundance was regressed against reporting rate for each species over all the sample squares where the species was reported by SABAP, or detected by us during sampling. As indicated, only squares with 10 or more record cards were included in the analysis and any squares with known bias were excluded. Values used were transformed using log (n + 1).

Results

Only four of the 10 species (whitetailed shrike, Monteiro's hornbill, Carp's black tit, Rüppell's korhaan) showed significant relationships between reporting rate and predicted abundance (see Table 17). As before, the relationship for the rockrunner was marginally significant and should be used with caution, while for the remaining species no useful trends were apparent. The lack of any relationship for Herero chat, Hartlaub's francolin and violet woodhoopoe is unsurprising. Because of the cryptic or locally rare nature of these species birds are easily missed unless specifically targeted during sampling. As a consequence SABAP data for these species are limited and the range of reporting rates obtained is minimal. The data for Rüppell's parrot and barecheeked babbler showed too much variability to provide any positive trend. The highly mobile nature of these two species and the tendency, at least for parrots, to be detected at or near an obvious water source will undoubtedly have affected reporting rates. Although a positive relationship for Rüppell's parrot was obtained previously, it was derived primarily from river estimates and it is unlikely to reflect true values. We therefore recommend that this regression equation is not used for any monitoring exercise. Equally, previous relationships for whitetailed shrike and Monteiro's hornbill were based on less robust data and should be replaced by the equations in Table 17.

Table 17 Relationship between SABAP reporting rate and predicted bird abundance.

Species	Regression equation	p	R^2 (%)
Rüppell's korhaan	log (n+1) abundance = 1.763 + 1.479 reporting rate†	0.002	40.4
Monteiro's hornbill	log (n+1) abundance = 2.422 + 0.784 reporting rate	0.017	14.3
Carp's black tit	log (n+1) abundance = 2.727 + 1.1908 reporting rate	0.004	24.3
Rockrunner	log (n+1) abundance = 2.328 + 0.689 reporting rate	0.052	11.3
Whitetailed shrike	log (n+1) abundance = 3.2044 + 0.649 reporting rate	0.038	12.23

† where reporting rate is expressed as a fraction

In summary, it is evident that success in deriving relationships between SABAP reporting rates and predicted bird abundance is variable and to a large extent dependent on the characteristics of the species. As one might expect, the inherent reduction in the reliability of data for rarer species is likely to result in relationships which are both unsatisfactory and not statistically significant. At most, the potential for monitoring using this approach is available for five of the 10 species. Arguably, these five species include those least in jeopardy, while for those which may be most vulnerable no simple approach exists for assessing changes in bird numbers from atlas data. Because of the different habitat requirements of the 10 species, minor environmental changes affecting one species may not have the same effect on others. However, substantial changes affecting most, or all, of the five species monitored in this way are likely to influence the other endemics similarly, given that their general habitat requirements show some similarities.

Other potential methods for population monitoring

Monitoring of those species for which the atlas approach is not appropriate might best be achieved through a combination of intensive studies within defined areas and more extensive regular surveying of selected sites.

Riverine species

For the primarily riverine species, violet woodhoopoe, Rüppell's parrot and barecheeked babbler, a simple monitoring scheme could be established based on regular surveying. Experienced ornithologists could walk selected sections of river courses regularly and count the numbers of birds of these species present, using tapes of bird calls to maximise bird detection. In order to detect sufficient numbers of groups to identify any changes, we suggest that a river distance of 20 km or more is surveyed at each site. If several sites were chosen each within easy reach of resident birders, regular surveying should be feasible. A sampling regime of perhaps two or three replicate surveys at each site within a defined time period each year, continued on a long-term basis, could yield data on both natural population fluxes and irregular population changes, at both local and national levels. Riverine species are particularly suited to this type of monitoring as density can be calculated simply as the number of birds (or groups) per km of river without the need for distance measures. Because no distance measures would be used, comparisons of bird abundance across areas would be possible, though care would need to be taken when comparing areas of thick riparian vegetation with sparsely vegetated areas because of differences in detectability. If each observer walked the same section each year, the effect of differences between observers would be minimised and relative changes over time would remain valid. A similar method has been used successfully in Finland since 1956 to monitor population levels of wintering and breeding birds (Hildén 1986). Sections of rivers should be selected to include a range from east to west and north to south, within several avi-vegetational zones. Some river sections suitable for this type of exercise are listed in Table 18, based on the detection of reasonable numbers of these species during our field sampling.

Table 18 Suggested sites for monitoring of riverine species.

River	Location	Species present †
Ugab	Brandberg	BB, RP, VW
Aba-Huab	Khorixas	BB, RP, VW?
Ugab	near Vingerklip	BB, RP, VW
Hoanib	near Warmquelle	BB, RP, VW?
Otjimakuru	east of Omaruru	RP, VW
Ombosiro / Omaruru	west of Omaruru	RP, VW
Okasoko	north of Omaruru	BB, RP, VW
Kahn	north of Karibib	RP, VW
Kunene	west of Ruacana	BB, RP, VW

† BB barecheeked babbler; RP Rüppell's parrot; VW violet woodhoopoe.

Herero chat and Hartlaub's francolin

The sparse and sporadic nature of these species renders line transect sampling inappropriate as a monitoring technique. The best approach for these species may be the long-term monitoring of population structure and demographic changes at several randomly selected sites. Significant change within these sites could be used to indicate general population trends. Indeed, while Hartlaub's francolin has been studied to some extent previously (Komen 1990), very little is known about the general ecology of Herero chat. Focal studies may provide important insights into the factors most likely to affect its population dynamics.

Recommendations for further work

1) One of the major limitations to deriving reliable population estimates concerns the ability adequately to identify distribution limits and unsuitable areas within distributions. Clearly, more detailed information on the ecological requirements of species such as barecheeked babbler, Rüppell's parrot and Hartlaub's francolin would allow more sensitive definitions of their distribution limits to be made. Work currently underway by Selman and Hunter (pers. comm.) will provide important information on foraging and breeding requirements of Rüppell's parrot. However, the effective use of such information at a population level will depend largely on the availability of maps at a sufficiently detailed scale.

2) Similarly, a more detailed assessment of aspects such as the effects of different types of land management and farming practices on bird numbers, and estimates of bird numbers within private conservation areas would be possible if detailed land use information in digital form became available.

3) As discussed in Chapter 3, the taxonomic status of violet woodhoopoe and Redbilled woodhoopoe is unclear and requires clarification. Several of the other species studied are conspecific to species with distributions along the eastern and / or northern fringes of the country. These include Carp's black tit and Southern black tit (*Parus niger*), Monteiro's hornbill and Bradfield's hornbill (*Tockus bradfieldi*), and Rüppell's parrot and Meyer's

parrot (*Poicephalus meyeri*). Of relevance to this work was the extent of overlap in the distributions of these pairs of species. Particular care was taken when sampling in areas of potential overlap to ensure that all sightings of these species were correctly identified. With the exception of the Waterberg area, none of the conspecifics was observed in any of the areas sampled. Both Monteiro's hornbill and Bradfield's hornbill were observed at Waterberg. Although the two species of tits are known to occur in this area, only Carp's tit was observed. Further work focusing on potential areas of overlap between conspecifics would enable the extent of interbreeding between these pairs of 'species' to be defined.

4) As indicated in Chapter 4, hotspots identified are largely contained within the Escarpment avi-vegetational zone and cover several classes of land tenure. If several sites were to be considered for the possible designation of a new protected area, detailed assessment of the differences in bird abundance in relation to land tenure may assist in the selection of sites. A range of 'paired' sites, identical with respect to other environmental variables such as rainfall and altitude, would need to be selected and surveyed intensively for direct comparison. As the sampling regime used in this study was not designed for this purpose, our data are both insufficiently detailed and unsuitable to be used for this type of analysis.

5) Although the work described in this project represents an assessment of optimal areas with respect to endemic birds, similar assessments are required for other groups of species such as Red data species, and other taxa such as amphibians, reptiles and mammals, to enable the identification of areas of generally high biodiversity or endemism. This would allow the congruence of hotspots to be assessed, and would provide information on optimal sites. These areas could then be prioritised for conservation on the basis of biodiversity status rather than by political or other non-biological motivations, thereby maximising the efficient use of limited resources for conservation management.

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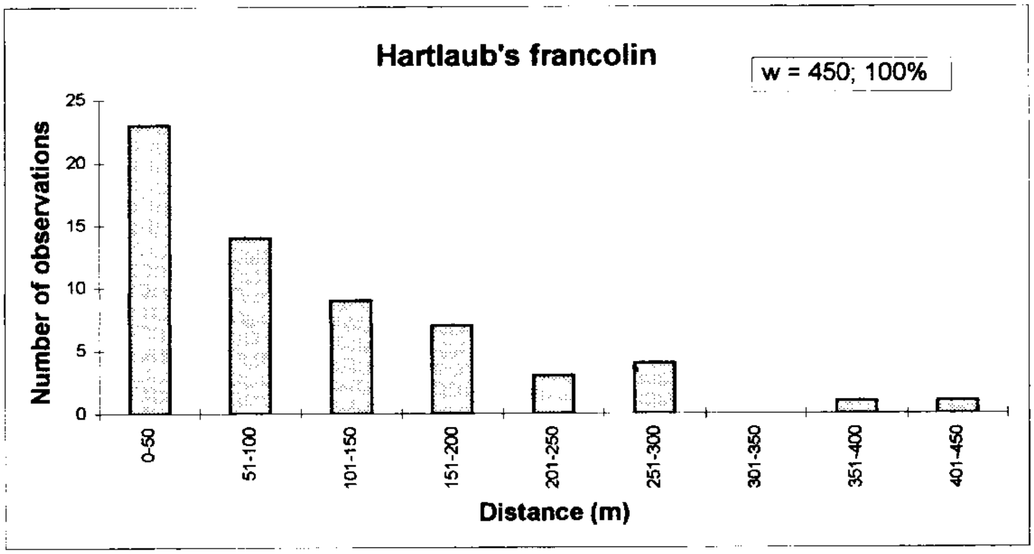
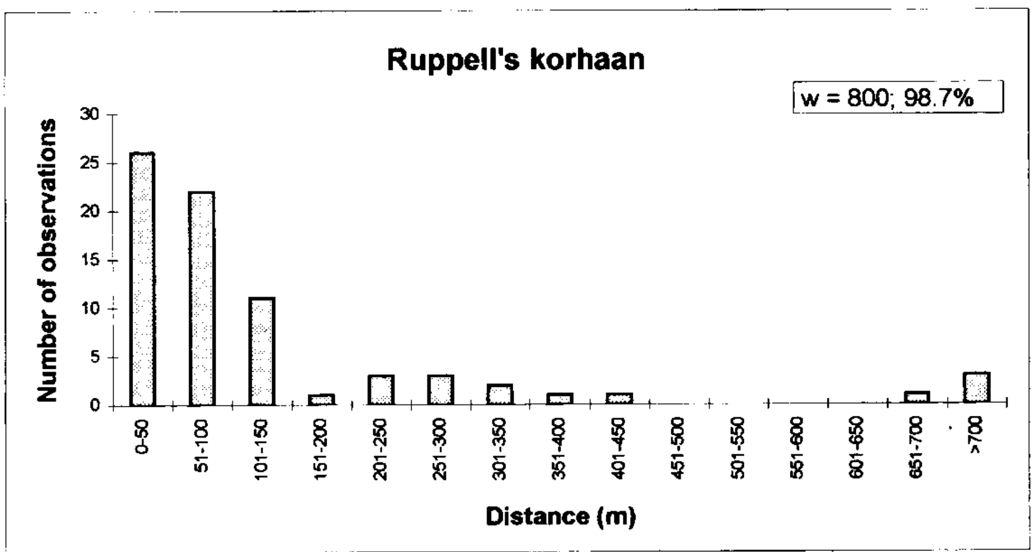
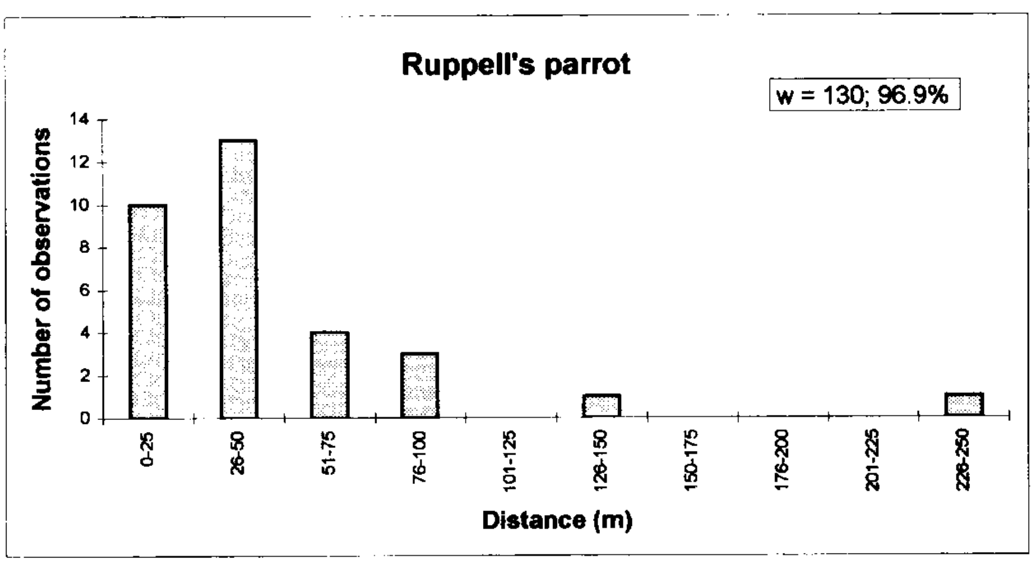
Appendix 1 Check sheet used for line transect sampling data recording.

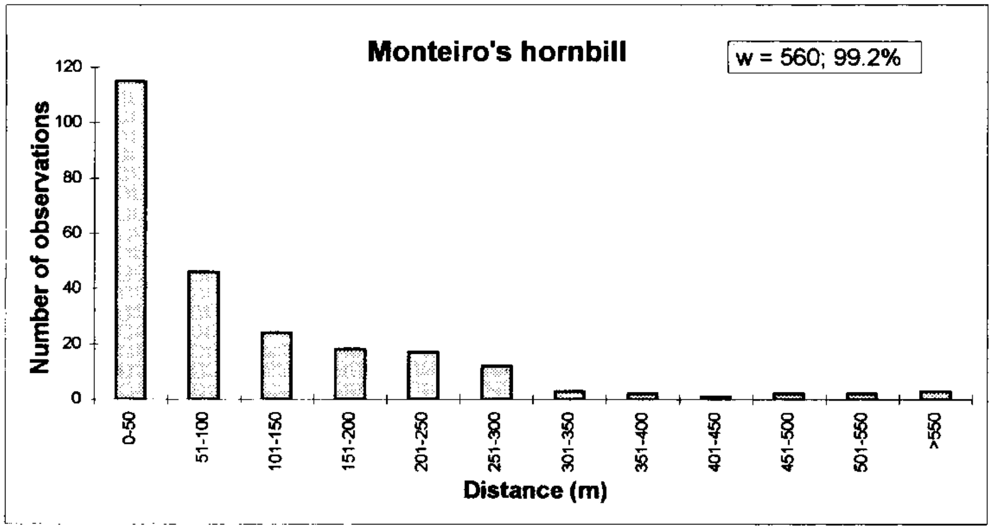
Appendix 2 Distance from the transect line at which birds were detected during sampling.

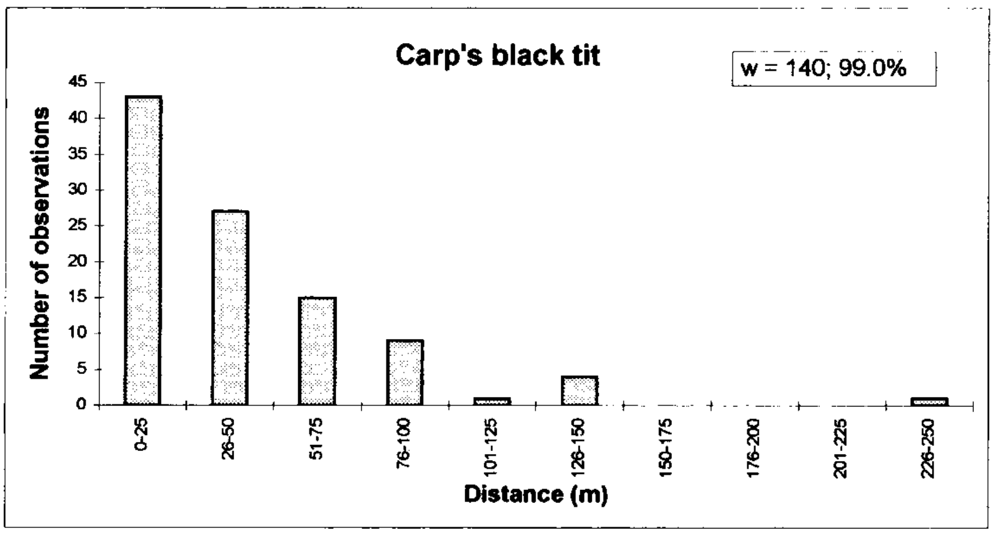
Values of w represent the cut-off distance used for the calculation of bird densities; the percentage figures indicate the number of all observations included in density calculations.

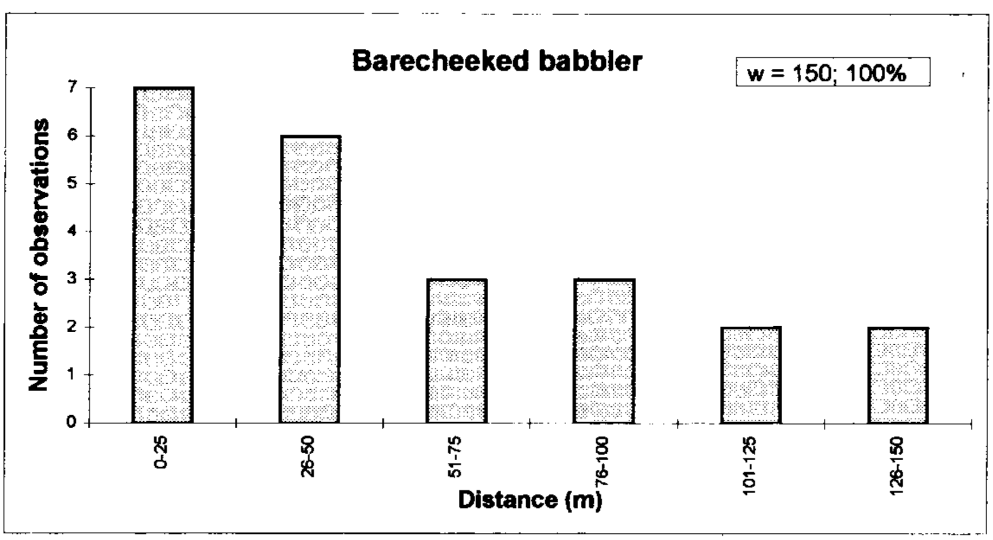

Hartlaub's francolin
w = 450; 100%
Number of observations
25
20
15
10
5
0
0-50
51-100
101-150
151-200
201-250
251-300
301-350
351-400
401-450
Distance (m)

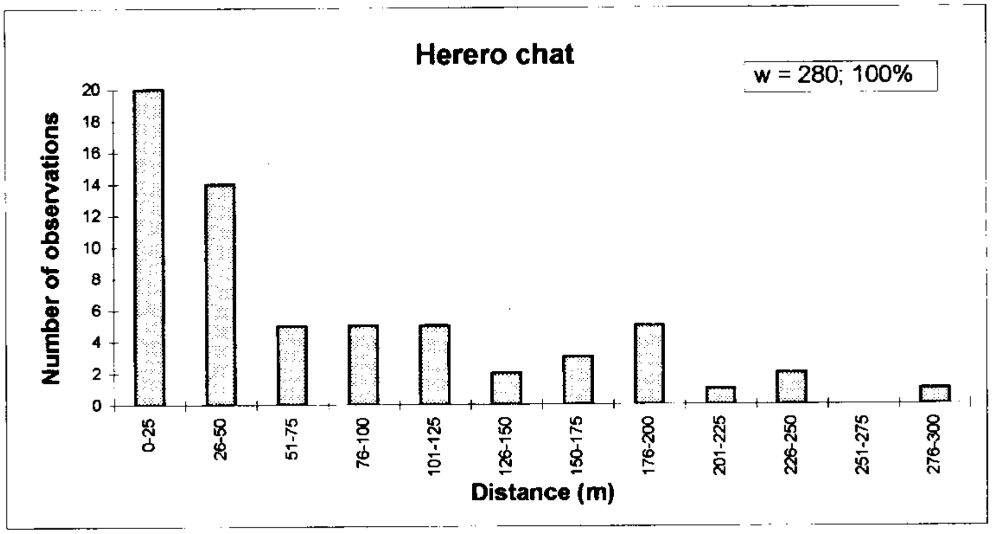

Ruppell's korhaan
w = 800; 98.7%
Number of observations
30
25
20
15
10
5
0
0-50
51-100
101-150
151-200
201-250
251-300
301-350
351-400
401-450
451-500
501-550
551-600
601-650
651-700
>700
Distance (m)

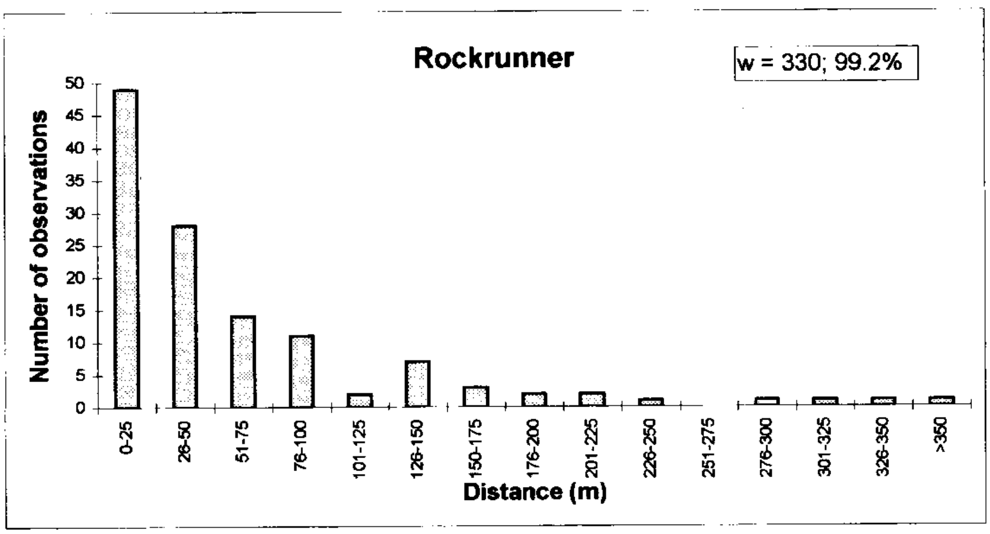

Ruppell's parrot
w = 130; 96.9%
Number of observations
14
12
10
8
6
4
2
0
0-25
26-50
51-75
76-100
101-125
126-150
150-175
176-200
201-225
226-250
Distance (m)

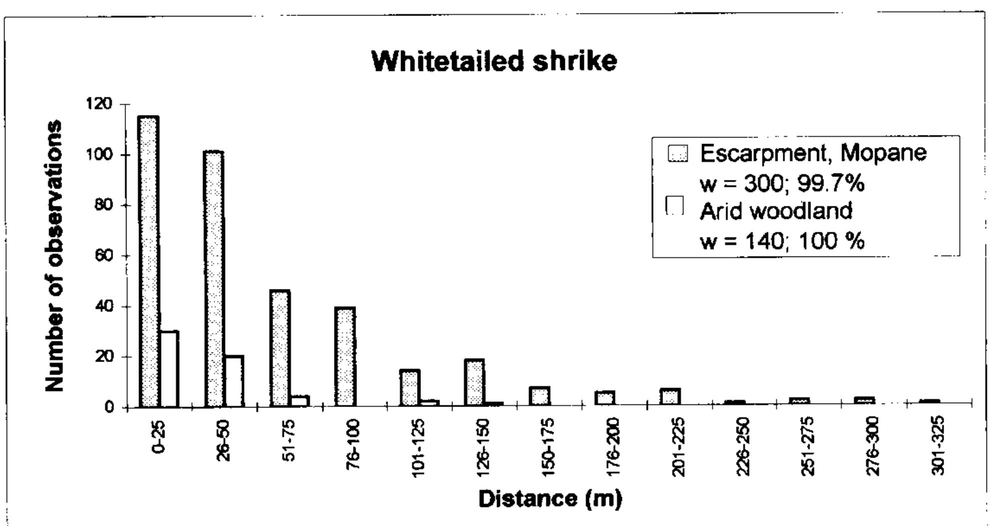

Monteiro's hornbill
w = 560; 99.2%
Number of observations
120
100
80
60
40
20
0
0-50
51-100
101-150
151-200
201-250
251-300
301-350
351-400
401-450
451-500
501-550
>550
Distance (m)


Carp's black tit
w = 140; 99.0%
Number of observations
45
40
35
30
25
20
15
10
5
0
0-25
26-50
51-75
76-100
101-125
126-150
150-175
176-200
201-225
226-250
Distance (m)


Barecheeked babbler
w = 150; 100%
Number of observations
7
6
5
4
3
2
1
0
0-25
26-50
51-75
76-100
101-125
126-150
Distance (m)


Herero chat
w = 280; 100%
Number of observations
Distance (m)
0-25
26-50
51-75
76-100
101-125
126-150
150-175
176-200
201-225
226-250
251-275
276-300


Rockrunner
w = 330; 99.2%
Number of observations
Distance (m)
0-25
26-50
51-75
76-100
101-125
126-150
150-175
176-200
201-225
226-250
251-275
276-300
301-325
326-350
>350


Whitetailed shrike
Escarpment, Mopane
w = 300; 99.7%
Arid woodland
w = 140; 100 %
Number of observations
Distance (m)
0-25
26-50
51-75
76-100
101-125
126-150
150-175
176-200
201-225
226-250
251-275
276-300
301-325

Appendix 3 Standard errors of regression statistics.

i) Standard errors regression statistics: one variable

Standard error of $\hat{Y}$, an estimated Y for specified value of X1

$$S_{\hat{y}} = \sqrt{S^2_{y.x}\left[\frac{1}{n} + \frac{(Xi - \overline{X})^2}{\sum x^2}\right]}$$

Where:

$$S^2\ y.x = \text{residual / n-2}$$

ii) Standard errors regression statistics: two variables

Standard error of $\hat{Y}$, an estimated Y for specified values of X1 and X2

$$s_{\hat{y}} = s_y\sqrt{1/n + c_{11}(x_1 - \overline{X}_1)^2 + c_{22}(x_2 - \overline{X}_2)^2 + 2c_{12}(x_1 - \overline{X}_1)(x_2 - \overline{X}_2)}$$

Where:

$$s_y = \left[\frac{(1 - R^2_{y1,2})\sum y^2}{n - k - 1}\right]^{1/2}$$ (k = no. of variables)

x_i = predicted value of variable i

$\overline{X}_i$ = standard deviation of variable i

c = SS-SP matrix

Appendix 4 Regression equations derived for each species: non-river transects.

Species	Transformation	Category	Regression equation
Hartlaub's francolin	sqrt (n)	Escarpment	0.4678 - 0.0250 alt
		Mopane	0.4678 + 1.5576 alt
		Arid Woodland	0. 4678 - 0.000146 alt
Rüppell's korhaan †	log (n+1)	Namib	- 0.2068 + 0.009823 rain
		Escarpment	0.382 - 0.001464 rain
		Nama Karoo	0.3289 + 0.00129 rain
Rüppell's parrot	log (n+1)	Escarpment	0.0947 + 0.000785 alt
		Mopane	1.5636 - 0.001064 alt
		Arid Woodland	0.6553 - 0.000403 alt
Monteiro's hornbill	sqrt (n)	Rainfall: 0 - 100 mm	0.5959 - 0.000629 alt
		Rainfall: 101 - 200 mm	1.3729 - 0.000629 alt
		Rainfall: 201 - 300 mm	1.8967 - 0.000629 alt
		Rainfall: 301 - 400 mm	2.7604 - 0.000629 alt
		Rainfall: 401 - 500 mm	1.545 - 0.000629 alt
		Rainfall: 501 - 600 mm	1.5488 - 0.000629 alt
Carp's black tit	sqrt (n)	Rainfall: 0 - 100 mm	0.4395 - 0.000206 alt
		Rainfall: 101 - 200 mm	2.0375 - 0.0011 alt
		Rainfall: 201 - 300 mm	4.1435 - 0.001915 alt
		Rainfall: 301 - 400 mm	4.6255 - 0.001858 alt
		Rainfall: 401 - 500 mm	2.0275 - 0.000919 alt
		Rainfall: 501 - 600 mm	1.0815 + 0.000173 alt
Barecheeked babbler	sqrt (n)	Escarpment	0.165 + 0.000108 alt
		Mopane	8.49- 0.005649 alt
		Arid Woodland	3.408 - 0.002088 alt
Herero chat	sqrt (n)	Escarpment	- 0.0065 + 0.000902 alt
Rockrunner	log (n+1)	Escarpment	0.0163 + 0.000105 alt
		Mopane	0.3774 - 0.000248 alt
		Arid Woodland	- 0.2186 + 0.000264 alt
Whitetailed shrike	log (n+1)	Escarpment	- 0.3848 + 0.004334 rain + 0.000265 alt
		Mopane	1.6441 - 0.003297 rain + 0.000265 alt
		Arid Woodland	1.0255 - 0.000932 rain + 0.000265 alt

[†] rainfall intervals of 50 mm were used for Rüppell's korhaan.

Appendix 5 Regression equations derived for each species: river transects.

Species	Transformation	Regression equation
Rüppell's parrot	log (n+1)	0.0276 + 0.000732 rain
Violet woodhoopoe	log (n+1)	- 0.0203 + 0.000844 rain
Monteiro's hornbill	not transformed	0.0155 + 0.00261 rain
Carp's black tit [†]	-	----
Barecheeked babbler	not transformed	- 1.180 + 0.0161 rain
Whitetailed shrike	log (n+1)	- 0.025 + 0.000308 alt

[†] see footnote to Table 9

Appendix 6 Predicted number of birds of each species in each QDS.

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
1612DD	2	3	0	0	5	9	0	2	1	5
1613CC	47	27	13	0	57	105	4	28	15	139
1613CD	18[†]	4	4	0	34	112	1	10	5	90
1711BB	0	8	0	0	0	0	0	0	0	0
1711BD	0	66	0	0	0	0	0	0	0	0
1711DA	0	1	0	0	0	0	0	0	0	0
1711DB	0	67	0	0	0	0	0	0	0	0
1711DD	0	55	0	0	0	0	0	0	0	0
1712AA	0	20	0	0	0	0	0	0	0	0
1712AB	0	5	0	0	0	0	0	0	0	0
1712AB	0	5	0	0	0	0	0	0	0	0
1712AC	0	68	0	0	0	0	0	0	0	0
1712AD	0	74	0	0	0	0	0	0	0	0
1712BA	55	122	0	0	7	13	0	62	30	35
1712BB	253	416	1	0	84	138	0	645	218	795
1712BC	434	834	0	0	11	45	0	675	233	137
1712BD	321	618	0	0	20	39	72	1235	328	853
1712CA	0	68	0	0	0	0	0	0	0	0
1712CB	0	91	0	0	0	0	0	0	0	0
1712CC	0	68	0	0	0	0	0	0	0	0
1712CD	0	107	0	0	0	0	0	0	0	0
1712DA	374	891	0	0	26	57	0	502	197	27
1712DB	356	681	121	0	0	19	71	1191	322	632
1712DC	515	883	0	0	2	40	0	669	235	8
1712DD	392	764	0	0	0	24	0	1052	300	395
1713AA	469	332	132	0	368	579	62	776	261	2007
1713AB	623	143	140	0	1051	3299	46	423	188	3389
1713AC	366	372	131	5	247	313	90	1087	309	2043
1713AD	440	177	130	0	628	1436	63	871	272	3871
1713BA	124[†]	0	32	2	322	991	22	108	45	1652
1713BC	471	5	135	3	1870	3964	75	537	252	10110
1713BD	324[†]	0	80	1	1984	3634	36	0	119	7424
1713CA	343	449	0	0	165	184	0	1212	326	1633
1713CB	390	216	0	0	429	924	66	1030	296	3466
1713CC	453	522	0	0	189	297	60	810	262	968
1713CD	455	291	130	0	348	531	0	841	266	2410
1713DA	429	23	128	0	1357	3025	63	772	278	9033
1713DB	351	0	0	0	2717	3434	0	0	318	16929
1713DC	389	59	0	0	891	2243	0	1006	293	7195
1713DD	399	0	127	2	2686	3809	78	83	296	15299
1714AC	183[†]	0	47	2	1135	2034	27	0	71	7088
1714AD	0[†]	0	1	0	15	25	0	0	1	111
1714CA	394	0	0	0	2850	3887	0	0	300	25824
1714CB	0	0	37	0	400	494	0	0	12	643
1714CC	358	0	121	0	2677	3286	73	0	321	23316
1714CD	0	0	57	0	530	657	140	0	16	694
1714DA	0	0	4	4	4	2	18	0	0	4
1714DB	0	0	27	26	26	15	129	0	0	25
1714DC	0	0	0	0	4	9	0	0	0	2
1714DD	0	0	15	14	14	8	70	0	0	14

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
1715CC	0	0	40	40	39	21	193	0	0	35
1811BB	0	36	0	0	0	0	0	0	0	0
1811BD	0	3	0	0	0	0	0	0	0	0
1812AA	0	68	0	0	0	0	0	0	0	0
1812AB	0	68	0	0	0	0	0	0	0	0
1812AC	0	66	0	0	0	0	0	0	0	0
1812AD	0	68	0	0	0	0	0	0	0	0
1812BA	0	127	0	0	0	0	0	0	0	0
1812BB	491	847	4	1	4	47	0	715	245	120
1812BC	0	123	0	0	0	0	0	0	0	0
1812BD	590	867	4	0	15	66	0	427	186	23
1812CA	0	20	0	0	0	0	0	0	0	0
1812CB	0	64	0	0	0	0	0	0	0	0
1812CD	0	22	0	0	0	0	0	0	0	0
1812DA	0	68	0	0	0	0	0	0	0	0
1812DB	0	93	0	0	0	0	0	0	0	0
1812DC	0	68	0	0	0	0	0	0	0	0
1812DD	0	103	0	0	0	0	0	0	0	0
1813AA	451	604	3	1	69	134	0	839	266	676
1813AB	568	364	9	6	481	806	24	564	217	1553
1813AC	551	688	146	4	12	56	1	588	222	342
1813AD	489	470	0	0	292	468	0	721	246	1107
1813BA	437	134	129	0	761	1947	61	860	270	4814
1813BB	379[†]	0	123	0	1986	3010	68	436	307	13585
1813BC	228	219	116	0	297	440	77	1420	352	4173
1813BD	107[†]	15	110	0	913	1114	84	1327	386	12560
1813CA	589	770	0	0	8	52	0	488	202	189
1813CB	538	560	7	4	129	216	1	632	228	747
1813CC	471	852	148	1	26	68	0	361	173	30
1813CD	620	627	150	2	43	104	1	362	177	319
1813DA	209	320	0	0	152	150	78	1454	356	2892
1813DB	142	74	112	0	539	889	0	1599	376	8418
1813DC	412	399	0	0	268	373	64	969	285	1716
1813DD	322	181	0	0	429	844	72	1232	326	4513
1814AA	357	0	0	0	2674	3281	0	0	319	18731
1814AB	489	0	0	0	747	917	0	0	21	996
1814AC	310	0	0	0	2591	3042	82	0	328	17195
1814AD	633	0	0	0	1007	1236	206	0	28	1976
1814CA	326	0	142	17	2211	2809	90	315	321	15178
1814CB	1542	0	0	0	2451	3008	491	0	74	5166
1814CC	379	6	30	27	1398	2668	140	789	298	10838
1814CD	355	0	3	2	2653	3429	12	1	291	15324
1814DA	47	0	7	0	79	97	0	0	2	156
1814DB	0	0	0	0	0	0	0	0	0	0
1814DC	607	0	223	0	1295	1717	0	0	50	2192
1814DD	0	0	0	0	75	122	0	0	5	82
1815DC	0	0	0	0	230	372	0	0	16	220
1816CD	0	0	0	0	8	11	63	0	3	0
1816DC	0	0	271	0	118	170	987	0	47	0
1816DD	0[†]	0	834	0	363	525	3042	0	144	0
1817CC	0	0	0	0	569	1050	1285	0	111	0
1817CD	0	0	515	0	575	1163	0	0	105	0
1817DC	0	0	0	0	575	1163	0	0	105	0
1817DD	0	0	0	0	575	1163	1077	0	105	0
1818CC	0	0	0	0	575	1163	0	0	105	0

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
1818CD	0	0	0	0	575	1163	0	0	105	0
1818DC	0	0	0	0	574	1164	0	0	106	0
1818DD	0	0	0	0	568	1154	0	0	110	0
1912BA	0	45	0	0	0	0	0	0	0	0
1912BB	0	68	0	0	0	0	0	0	0	0
1912BC	0	10	0	0	0	0	0	0	0	0
1912BD	0	67	0	0	0	0	0	0	0	0
1912DB	0	43	0	0	0	0	0	0	0	0
1912DD	0	9	0	0	0	0	0	0	0	0
1913AA	0	80	0	0	0	0	0	0	0	0
1913AB	0	1192	0	0	0	0	0	0	0	0
1913AC	0	68	0	0	0	0	0	0	0	0
1913AD	0	393	0	0	0	0	0	0	0	0
1913BA	422	504	151	3	385	696	54	336	167	655
1913BB	479[†]	283	134	2	406	685	66	771	250	2391
1913BC	554	593	4	2	87	184	1	450	194	444
1913BD	603	387	151	7	506	876	81	475	200	1293
1913CA	0	67	0	0	0	0	0	0	0	0
1913CB	0	111	0	0	0	0	0	0	0	0
1913CC	0	66	0	0	0	0	0	0	0	0
1913CD	0	67	0	0	0	0	0	0	0	0
1913DA	500	688	17	6	19	70	0	690	231	431
1913DB	463	519	136	3	162	271	5	755	251	898
1913DC	0	608	0	0	0	0	0	0	0	0
1913DD	557	604	15	8	21	70	57	560	216	523
1914AA	468	63	0	0	1033	2981	0	722	247	5940
1914AB	367[†]	0	125	0	1698	2845	85	498	275	11126
1914AC	524	174	161	21	780	1942	155	608	225	3357
1914AD	449[†]	18	139	8	1071	3070	99	785	257	7247
1914BA	1423[†]	0	362	0	2331	3045	1064	0	85	4650
1914BB	363	0	502	0	1682	2498	0	0	93	2550
1914BC	356[†]	0	121	0	1595	2481	70	657	315	12279
1914BD	1665	0	246	0	2650	3252	0	0	76	6009
1914CA	450	295	133	2	360	566	69	787	257	2248
1914CB	439	98	9	8	970	2725	39	794	258	4873
1914CC	370	444	0	0	174	235	0	1008	291	1457
1914CD	444	220	13	11	533	1167	56	785	256	3014
1914DA	411	7	156	21	979	2550	196	942	281	8467
1914DB	2412	0	5	4	1919	3015	23	0	115	6471
1914DC	480[†]	70	209	50	1168	3368	388	688	240	5305
1914DD	4444[†]	0	1341	37	1152	3333	4931	0	224	7377
1915AA	62	0	0	0	1060	1679	0	0	70	1350
1915AB	0	0	2	2	1308	2120	9	0	92	1500
1915AC	1612	0	0	0	2674	3325	0	0	80	5432
1915AD	1152	0	4	4	2785	3791	18	0	118	4756
1915BA	0[†]	0	0	0	1854	3006	2751	0	130	1943
1915BB	0	0	320	0	784	1272	1167	0	55	692
1915BC	605	0	0	0	3003	4486	0	0	170	3897
1915BD	129	0	0	0	2123	3324	4228	0	204	2230
1915CA	1986	0	368	0	2714	3476	0	0	92	5917
1915CB	1737	0	2	2	2666	3303	9	0	79	5207
1915CC	4035[†]	0	1157	10	1813	3749	4177	3	203	6044
1915CD	1805	0	301	0	2537	3237	758	0	82	5764
1915DA	1650	0	0	0	2656	3271	0	0	76	4059
1915DB	1482	0	363	0	1295	1632	1004	0	91	2052

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
1915DC	1663	0	0	0	2646	3248	0	0	75	4224
1915DD	1662	0	0	0	2099	2580	0	0	75	2960
1916AA	0	0	0	0	718	1127	2555	0	121	1078
1916AB	0†	0	0	0	504	728	4222	0	199	443
1916AC	1	0	0	0	567	818	0	0	224	349
1916AD	66	0	0	0	546	785	4472	0	213	0
1916BA	0	0	0	0	569	821	4760	0	225	0
1916BB	8	0	0	0	568	820	4740	0	224	0
1916BC	441	0	0	0	511	722	0	0	185	0
1916BD	1124	0	591	0	424	911	1914	0	124	0
1916CA	1511	0	0	0	371	483	0	0	89	0
1916CB	1530	0	0	0	369	479	874	0	92	0
1916CC	1662	0	246	0	500	631	0	0	77	1107
1916CD	624	0	0	0	351	448	265	0	261	19
1916DA	1629	0	0	0	347	454	523	0	76	0
1916DB	610	0	192	0	338	1086	241	0	281	0
1916DC	628	0	0	0	351	448	0	0	270	0
1916DD	744	0	211	0	350	448	0	0	271	0
1917AA	85	0	0	0	541	963	1259	0	137	0
1917AB	254	0	392	0	486	1201	0	0	172	0
1917AC	628	0	0	0	358	1223	290	0	249	0
1917AD	627	0	212	0	356	1257	251	0	272	0
1917BA	360	0	0	0	449	1217	604	0	200	0
1917BB	472	0	0	0	411	1234	0	0	230	0
1917BC	607†	0	0	0	331	1272	214	0	302	0
1917BD	594	0	0	0	320	1278	198	0	314	0
1917CA	624†	0	207	0	351	1257	246	0	275	0
1917CB	592†	0	168	0	321	1276	199	0	312	0
1917CC	598	0	0	0	315	499	0	0	314	0
1917CD	544	0	0	0	255	594	102	0	388	0
1917DA	481†	0	12	0	189	1359	0	0	479	0
1917DB	498	0	19	0	203	1348	0	0	455	0
1917DC	548	0	98	0	264	864	117	0	376	0
1918AA	430	0	0	0	426	1228	0	0	218	0
1918AB	393	0	0	0	439	1222	0	0	209	0
1918AC	623	0	0	0	351	1260	0	0	278	0
1918AD	630	0	0	0	356	1249	0	0	271	0
1918BA	195	0	0	0	506	1190	0	0	157	0
1918BB	282	0	0	0	474	861	0	0	180	0
1918BC	629	0	0	0	353	770	0	0	271	0
1918BD	624	0	0	0	354	453	0	0	269	0
1918CA	620	0	0	0	349	1238	243	0	278	0
1918CB	627	0	0	0	353	718	0	0	271	0
1918DA	637†	0	0	0	365	473	0	0	258	0
1918DB	648†	0	0	0	384	507	0	0	241	0
1919AC	349	0	0	0	445	610	0	0	196	0
1919CA	487	0	0	0	394	524	0	0	230	0
2013AA	0	36	0	0	0	0	0	0	0	0
2013AB	0	67	0	0	0	0	0	0	0	0
2013AC	0	2	0	0	0	0	0	0	0	0
2013AC	0	2	0	0	0	0	0	0	0	0
2013AD	0	66	0	0	0	0	0	0	0	0
2013BA	0	229	0	0	0	0	0	0	0	0
2013BB	586	671	137	0	7	50	0	486	199	280
2013BC	0	67	0	0	0	0	0	0	0	0

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2013BD	0	777	0	0	0	0	0	0	0	0
2013CB	0	44	0	0	0	0	0	0	0	0
2013CD	0	19	0	0	0	0	0	0	0	0
2013DA	0	67	0	0	0	0	0	0	0	0
2013DB	0	291	0	0	0	0	0	0	0	0
2013DC	0	67	0	0	0	0	0	0	0	0
2013DD	0	70	0	0	0	0	0	0	0	0
2014AA	496	557	0	0	46	106	56	701	239	677
2014AB	611	376	153	7	544	971	73	385	181	1247
2014AC	310	612	153	3	42	73	47	333	163	285
2014AD	446	516	155	4	227	407	50	284	156	531
2014BA	592†	192	182	34	809	1998	170	480	200	2799
2014BB	480	91	134	2	1089	3259	65	693	241	4677
2014BC	582	311	153	10	514	874	97	499	204	1757
2014BD	521	188	140	4	620	1397	73	616	226	3032
2014CA	306	690	3	1	43	74	0	245	136	129
2014CB	494	575	152	3	31	72	6	299	160	361
2014CC	0	839	0	0	0	0	0	0	0	0
2014CD	149	608	10	5	67	95	3	180	128	200
2014DA	640	448	12	8	418	746	26	397	184	903
2014DB	586	282	140	1	505	875	3	489	202	1886
2014DC	538	528	151	3	206	387	48	315	164	501
2014DD	589	376	162	12	634	1148	95	333	169	1119
2015AA	441	23	0	0	1034	2941	60	815	261	6924
2015AB	1898	0	337	0	1015	2047	904	2	88	7552
2015AC	470	93	0	0	1077	3176	57	722	246	4693
2015AD	4686	0	1380	12	1132	3377	5049	11	230	7980
2015BA	1825	0	310	0	2351	3092	0	0	84	5645
2015BB	1836	0	314	0	2678	3367	0	0	84	3885
2015BC	4421	0	1320	25	1533	3665	4843	0	223	6080
2015BD	4327	0	1293	32	3198	5118	4743	0	218	4216
2015CA	527	172	10	8	787	2107	42	605	224	3194
2015CB	551	73	186	42	1318	4213	266	552	214	4704
2015CC	632	253	24	19	580	1012	93	415	187	2029
2015CD	472	140	147	13	893	2451	123	698	241	3859
2015DA	463	6	10	9	1094	3197	45	733	248	7796
2015DB	2906	0	17	15	2505	3775	79	3	149	5590
2015DC	391†	20	172	43	955	2334	286	998	289	7728
2015DD	622	0	20	18	1877	2606	93	0	269	8424
2016AA	657	0	293	0	2549	3453	489	0	221	6450
2016AB	626	0	0	0	686	879	0	0	266	4063
2016AC	656	0	0	0	2794	3786	616	0	225	6773
2016AD	618	0	201	0	1429	1723	0	0	278	6763
2016BA	627	0	0	0	350	448	0	0	270	0
2016BB	621	0	0	0	344	438	0	0	277	0
2016BC	615	0	0	0	340	432	0	0	281	1276
2016BD	526	0	0	0	224	249	0	0	421	0
2016CA	624	0	0	0	2634	3232	0	0	260	7320
2016CB	611	0	192	0	2105	2541	0	0	287	6958
2016CC	572	0	0	0	2453	2700	0	0	339	8162
2016CD	505	0	22	0	2186	1903	0	0	446	8444
2016DA	507	0	24	0	207	220	0	0	445	6286
2016DB	496	0	0	0	187	191	0	0	465	3061
2016DC	515†	0	36	0	1546	1464	0	0	433	7961
2016DD	586	0	0	0	1130	1381	0	0	327	7064

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2017AA	507	0	0	0	203	215	0	0	448	0
2017AB	586	0	0	0	302	371	0	0	328	0
2017AC	558[†]	0	32	0	277	248	0	0	1310	0
2017AD	682[†]	0	145	0	451	415	0	0	2336	527
2017CA	668[†]	0	176	0	427	436	147	0	1712	3912
2017CB	623[†]	0	220	11	999	1226	300	0	270	6310
2017CC	624	0	0	0	1945	2393	0	0	269	6697
2017CD	626[†]	0	265	54	2684	3227	265	0	269	6826
2017DA	622	0	69	68	2263	2698	331	0	267	6762
2017DC	626	0	231	20	2650	3227	100	0	269	6757
2113BA	0	44	0	0	0	0	0	0	0	0
2113BB	0	67	0	0	0	0	0	0	0	0
2113BC	0	4	0	0	0	0	0	0	0	0
2113BD	0	58	0	0	0	0	0	0	0	0
2113DB	0	23	0	0	0	0	0	0	0	0
2113DD	0	2	0	0	0	0	0	0	0	0
2114AA	0	243	0	0	0	0	0	0	0	0
2114AB	235	672	0	0	39	62	0	193	113	105
2114AC	0	67	0	0	0	0	0	0	0	0
2114AD	0	692	0	0	0	0	0	0	0	0
2114BA	232[†]	559	86	3	75	145	7	151	84	228
2114BB	624	434	1	0	570	1027	1	383	180	881
2114BC	608	643	5	3	20	66	0	339	164	315
2114BD	605	483	0	0	363	638	0	459	195	759
2114CA	0	67	0	0	0	0	0	0	0	0
2114CB	0	161	0	0	0	0	0	0	0	0
2114CC	0	47	0	0	0	0	0	0	0	0
2114CD	0	67	0	0	0	0	0	0	0	0
2114DA	0	1128	0	0	0	0	0	0	0	0
2114DB	545	640	11	6	110	211	0	321	156	395
2114DC	0	449	0	0	0	0	0	0	0	0
2114DD	0	1308	0	0	0	0	0	0	0	0
2115AA	482	305	0	0	379	592	0	682	239	1943
2115AB	468	195	2	2	532	1155	0	722	246	3106
2115AC	553	350	152	11	495	830	0	526	208	1474
2115AD	472	230	29	23	423	676	0	697	241	2689
2115BA	370	46	139	15	877	2099	0	1062	299	6962
2115BB	613[†]	0	207	8	1463	2241	0	40	277	8768
2115BC	454[†]	83	175	40	1081	3019	0	748	250	5114
2115BD	371[†]	1	148	25	958	2156	0	1015	299	10005
2115CA	514	429	12	8	408	663	0	608	224	1148
2115CB	455	285	4	3	354	531	0	745	249	2204
2115CC	466	601	2	1	67	127	0	701	234	667
2115CD	465	398	141	8	342	520	0	705	242	1417
2115DA	251[†]	151	115	0	480	955	0	1255	335	4806
2115DB	333[†]	23	20	18	863	2060	0	1079	305	7834
2115DC	449[†]	234	153	19	426	709	0	735	247	2726
2115DD	425[†]	99	145	16	970	2624	0	848	265	4880
2116AA	570	0	136	7	2444	2656	0	0	344	8507
2116AB	533	0	116	35	2341	2280	0	0	399	8516
2116AC	619	0	47	44	2350	2960	0	39	270	8471
2116AD	535[†]	0	109	21	2343	2326	0	0	390	8799
2116BA	587	0	0	0	2496	2835	0	0	320	7540
2116BB	624	0	0	0	2625	3222	0	0	268	6963
2116BC	570	0	126	0	2426	2632	0	0	346	7976

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2116BD	624	0	0	0	2621	3217	0	0	268	7109
2116CA	616	0	221	17	1052	1947	0	84	270	8709
2116CB	605	0	26	25	2582	3061	0	1	286	8226
2116CC	347	9	131	11	812	1815	0	1140	311	9048
2116CD	343	0	120	2	2263	2915	0	227	315	14003
2116DA	540	0	6	5	2338	2361	0	0	381	8385
2116DB	556	0	0	0	2377	2494	0	0	363	7905
2116DC	559	0	0	0	2396	2561	0	0	354	8325
2116DD	592	0	179	12	2525	2909	0	0	307	7503
2117AA	0	0	210	0	2625	3222	0	0	268	6889
2117AB	0	0	0	0	2625	3222	0	0	268	6816
2117AC	0	0	0	0	2621	3217	0	0	268	6884
2117AD	0	0	0	0	1514	1862	0	0	285	6771
2117BA	0	0	0	0	1901	2339	0	0	268	6669
2117BB	0	0	0	0	432	547	0	0	266	6425
2117BC	0	0	0	0	311	384	0	0	321	6851
2117BD	0	0	63	0	234	265	0	0	405	5502
2117CA	0	0	0	0	2204	2372	0	0	353	7445
2117CB	0	0	0	0	236	255	0	0	423	7696
2117CC	0	0	156	10	2475	2767	0	0	326	7330
2117CD	0	0	50	27	1124	1033	0	0	446	7982
2117DA	0	0	0	0	184	187	0	0	464	7821
2117DB	0	0	0	0	184	187	0	0	464	6147
2117DC	0	0	0	0	184	187	0	0	463	7916
2117DD	0	0	0	0	850	721	0	0	463	8016
2118AC	0	0	0	0	187	191	0	0	462	9
2118CA	0	0	0	0	184	187	0	0	464	591
2118CB	0	0	0	0	184	187	0	0	464	0
2118CC	0	0	0	0	860	728	0	0	463	7236
2118CD	0	0	0	0	186	188	0	0	463	3319
2214AA	0	3	0	0	0	0	0	0	0	0
2214AB	0	57	0	0	0	0	0	0	0	0
2214AD	0	18	0	0	0	0	0	0	0	0
2214BA	0	69	0	0	0	0	0	0	0	0
2214BB	0	486	0	0	0	0	0	0	0	0
2214BC	0	66	0	0	0	0	0	0	0	0
2214BD	0	66	0	0	0	0	0	0	0	0
2214CD	0	4	0	0	0	0	0	0	0	0
2214CD	0	4	0	0	0	0	0	0	0	0
2214DA	0	62	0	0	0	0	0	0	0	0
2214DB	0	66	0	0	0	0	0	0	0	0
2214DC	0	59	0	0	0	0	0	0	0	0
2214DD	0	66	0	0	0	0	0	0	0	0
2215AA	0	1312	0	0	0	0	0	0	0	0
2215AB	545	556	14	8	108	201	0	549	211	633
2215AC	0	349	0	0	0	0	0	0	0	0
2215AD	528	644	2	1	6	45	0	589	216	373
2215BA	437[†]	365	139	7	346	519	0	796	255	1706
2215BB	381	193	122	0	483	962	0	1000	289	3649
2215BC	554	474	149	8	348	601	0	538	209	866
2215BD	516	298	148	11	445	720	0	593	220	1911
2215CA	0	66	0	0	0	0	0	0	0	0
2215CB	461[†]	752	143	1	27	72	0	342	162	97
2215CC	0	66	0	0	0	0	0	0	0	0
2215CD	0	78	0	0	0	0	0	0	0	0

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2215DA	508	517	146	7	178	287	0	596	218	787
2215DB	399	318	127	3	285	395	0	925	276	2106
2215DC	462	582	1	0	114	194	0	695	232	597
2215DD	372	360	0	0	262	357	0	982	284	1850
2216AA	383	50	122	0	896	2288	0	991	287	6547
2216AB	362	0	130	9	1289	2343	0	806	302	11320
2216AC	474	128	149	15	965	2736	0	676	236	3978
2216AD	405	13	24	22	986	2625	0	896	272	8070
2216BA	0	0	292	28	2714	3546	0	2	236	7649
2216BB	0	0	267	56	2664	3194	0	0	267	7358
2216BC	0	0	0	0	1964	2164	0	24	367	9097
2216BD	0	0	88	22	2267	2137	0	0	413	8681
2216CA	269	168	0	0	476	964	0	1257	325	4356
2216CB	198	20	0	0	663	1259	0	1424	348	9275
2216CC	209	219	0	0	236	334	0	1376	341	3765
2216CD	170	44	110	0	621	1105	0	1472	355	8246
2216DA	0	0	4	0	1533	1356	0	45	458	10102
2216DB	0	0	0	0	1887	1211	0	0	581	10376
2216DC	0	0	0	0	760	883	0	52	461	10422
2216DD	0	0	0	0	1590	878	0	0	627	11330
2217AA	0	0	2	2	2088	1709	0	0	489	8755
2217AB	0	0	0	0	1942	1386	0	0	539	8846
2217AC	0	0	56	16	2025	1547	0	0	532	9331
2217AD	0	0	41	40	1997	1367	0	0	547	9295
2217BA	0	0	0	0	1157	906	0	0	488	8266
2217BB	0	0	0	0	1270	1058	0	0	463	8086
2217BC	0	0	62	60	2175	1734	0	0	462	8484
2217BD	0	0	18	18	2132	1734	0	0	462	8408
2217CA	0	0	1	1	1806	1034	0	0	628	10353
2217CB	0	0	0	0	1844	1114	0	0	605	10045
2217CC	0[†]	0	31	29	1965	1326	0	0	554	10368
2217CD	0	0	0	0	1989	1454	0	0	523	9903
2217DA	0	0	10	9	2121	1731	0	0	461	8816
2217DB	0	0	19	19	2169	1845	0	0	446	8743
2217DC	0	0	17	0	2144	1841	0	0	446	9322
2217DD	0	0	6	6	2248	2572	0	0	325	8519
2218AA	0	0	0	0	2118	1737	0	0	463	8291
2218AB	0	0	0	0	1434	1189	0	0	463	8124
2218AC	0	0	8	0	2134	1792	0	0	454	8473
2218AD	0	0	0	0	2363	2477	0	0	362	7717
2218CA	0	0	0	0	2310	2326	0	0	381	8314
2218CB	0	0	0	0	2589	3177	0	0	264	7356
2218CC	0	0	0	0	2221	2853	0	0	269	8137
2314AB	0	16	0	0	0	0	0	0	0	0
2314AD	0	6	0	0	0	0	0	0	0	0
2314BA	0	66	0	0	0	0	0	0	0	0
2314BB	0	66	0	0	0	0	0	0	0	0
2314BC	0	66	0	0	0	0	0	0	0	0
2314BD	0	66	0	0	0	0	0	0	0	0
2314CB	0	1	0	0	0	0	0	0	0	0
2314CD	0	2	0	0	0	0	0	0	0	0
2314DA	0	64	0	0	0	0	0	0	0	0
2314DB	0	66	0	0	0	0	0	0	0	0
2314DC	0	64	0	0	0	0	0	0	0	0
2314DD	0	66	0	0	0	0	0	0	0	0

QDS	Hartlaub’s francolin	Rüppell’s korhaan	Rüppell’s parrot	Violet wood-hoopoe	Monteiro’s hornbill	Carp’s black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2315AA	0	66	0	0	0	0	0	0	0	0
2315AB	0	66	0	0	0	0	0	0	0	0
2315AC	0	66	0	0	0	0	0	0	0	0
2315AD	0	66	0	0	0	0	0	0	0	0
2315BA	0	875	0	0	0	0	0	0	0	0
2315BB	495	521	0	0	212	340	0	627	223	834
2315BC	0	389	0	0	0	0	0	0	0	0
2315BD	526†	590	0	0	5	44	0	573	213	506
2315CA	0	66	0	0	0	0	0	0	0	0
2315CB	0	66	0	0	0	0	0	0	0	0
2315CC	0	66	0	0	0	0	0	0	0	0
2315CD	0	66	0	0	0	0	0	0	0	0
2315DA	0	298	0	0	0	0	0	0	0	0
2315DB	500	595	0	1	59	121	0	618	221	532
2315DC	0	305	0	0	0	0	0	0	0	0
2315DD	503	552	0	0	136	231	0	613	219	674
2316AA	418	340	146	15	331	465	0	839	262	1913
2316AB	153	128	119	8	436	657	0	1320	360	5884
2316AC	377	390	123	0	261	377	0	856	274	1671
2316AD	85	150	105	0	416	588	0	1288	386	5505
2316BA	0	0	0	0	475	554	0	42	508	11417
2316BB	0	0	65	58	638	720	0	0	459	10771
2316BC	49	64	0	0	506	640	0	1581	394	7838
2316BD	0	0	21	18	575	812	0	33	433	11136
2316CA	311	325	0	0	250	356	0	833	300	2448
2316CB	45	141	0	0	423	497	0	1234	405	5890
2316CC	237	294	0	2	187	233	0	1025	332	2863
2316CD	69	157	0	0	373	462	0	1613	383	5210
2316DA	55	99	0	0	521	682	0	1709	387	6611
2316DC	139	128	0	0	598	997	0	1537	362	5533
2317AA	0	0	0	35	1046	1360	0	0	379	9690
2317AB	0	0	0	0	1047	1445	0	0	367	9445
2317AC	0	0	0	5	777	1696	0	0	268	9384
2317BA	0	0	180	18	987	1755	0	0	290	8889
2317BB	0	0	0	0	768	1679	0	0	272	8834
2414AB	0	6	0	0	0	0	0	0	0	0
2414BA	0	65	0	0	0	0	0	0	0	0
2414BB	0	65	0	0	0	0	0	0	0	0
2414BC	0	46	0	0	0	0	0	0	0	0
2414BD	0	65	0	0	0	0	0	0	0	0
2414DA	0	22	0	0	0	0	0	0	0	0
2414DB	0	65	0	0	0	0	0	0	0	0
2414DD	0	53	0	0	0	0	0	0	0	0
2415AA	0	65	0	0	0	0	0	0	0	0
2415AB	0	65	0	0	0	0	0	0	0	0
2415AC	0	65	0	0	0	0	0	0	0	0
2415AD	0	65	0	0	0	0	0	0	0	0
2415BA	0	352	0	0	0	0	0	0	0	0
2415BB	0	2471	0	0	0	0	0	0	0	0
2415BC	0	418	0	0	0	0	0	0	0	0
2415BD	0	576	0	0	0	0	0	0	0	0
2415CA	0	65	0	0	0	0	0	0	0	0
2415CB	0	65	0	0	0	0	0	0	0	0
2415CC	0	65	0	0	0	0	0	0	0	0
2415CD	0	65	0	0	0	0	0	0	0	0

QDS	Hartlaub's francolin	Rüppell's korhaan	Rüppell's parrot	Violet wood-hoopoe	Monteiro's hornbill	Carp's black tit	Bare-cheeked babbler	Herero chat	Rock-runner	White-tailed shrike
2415DA	0	395	0	0	0	0	0	0	0	0
2415DB	0	604	0	0	0	0	0	0	0	0
2415DC	0	287	0	0	0	0	0	0	0	0
2415DD	0	1878	0	0	0	0	0	0	0	0
2416AA	189	683	0	0	127	139	0	931	337	2317
2416AB	196†	215	0	0	133	128	0	1223	354	3873
2416AC	245	380	0	0	180	213	0	1144	327	1943
2416AD	0	271	0	0	0	0	0	0	0	0
2416BA	0	178	0	0	0	0	0	0	0	0
2416BC	0	220	0	0	0	0	0	0	0	0
2416CA	0	380	0	0	0	0	0	0	0	0
2416CB	0	286	0	0	0	0	0	0	0	0
2416CC	0	543	0	0	0	0	0	0	0	0
2416CD	0	293	0	0	0	0	0	0	0	0
2416DA	0	250	0	0	0	0	0	0	0	0
2416DC	0	264	0	0	0	0	0	0	0	0
2514BB	0	38	0	0	0	0	0	0	0	0
2514BD	0	43	0	0	0	0	0	0	0	0
2514DB	0	36	0	0	0	0	0	0	0	0
2515AA	0	65	0	0	0	0	0	0	0	0
2515AB	0	65	0	0	0	0	0	0	0	0
2515AC	0	65	0	0	0	0	0	0	0	0
2515AD	0	65	0	0	0	0	0	0	0	0
2515BA	0	316	0	0	0	0	0	0	0	0
2515BB	0	2002	0	0	0	0	0	0	0	0
2515BC	0	388	0	0	0	0	0	0	0	0
2515BD	0	2022	0	0	0	0	0	0	0	0
2515CA	0	64	0	0	0	0	0	0	0	0
2515CB	0	65	0	0	0	0	0	0	0	0
2515CD	0	64	0	0	0	0	0	0	0	0
2515DA	0	421	0	0	0	0	0	0	0	0
2515DB	0	1850	0	0	0	0	0	0	0	0
2515DC	0	498	0	0	0	0	0	0	0	0
2515DD	0	1543	0	0	0	0	0	0	0	0
2516AA	0	792	0	0	0	0	0	0	0	0
2516AB	0	333	0	0	0	0	0	0	0	0
2516AC	0	410	0	0	0	0	0	0	0	0
2516AD	0	817	0	0	0	0	0	0	0	0
2516BA	0	269	0	0	0	0	0	0	0	0
2516BC	0	282	0	0	0	0	0	0	0	0
2516CA	0	541	0	0	0	0	0	0	0	0
2516CB	0	329	0	0	0	0	0	0	0	0
2516CC	0	585	0	0	0	0	0	0	0	0
2516CD	0	397	0	0	0	0	0	0	0	0
2516DA	0	301	0	0	0	0	0	0	0	0
2516DC	0	322	0	0	0	0	0	0	0	0
2615BA	0	589	0	0	0	0	0	0	0	0
2615BB	0	1304	0	0	0	0	0	0	0	0
2616AA	0	2362	0	0	0	0	0	0	0	0
2616AB	0	592	0	0	0	0	0	0	0	0
2616AC	0	1653	0	0	0	0	0	0	0	0
2616AD	0	2357	0	0	0	0	0	0	0	0
2616BA	0	413	0	0	0	0	0	0	0	0
2616BC	0	593	0	0	0	0	0	0	0	0

† indicates those QDS reported by SABAP to contain Hartlaub's francolin.

Appendix 7 Index ranking of the top 40 % of QDS predicted to contain any of nine species of endemic birds.

Rank	QDS	No of species	RK ‡
1	1914AD	9	y
2	2015CD	9	y
3	1713BA	9	n
4	2014BD	9	y
5	1914DA	9	y
6	1713BC	9	y
7	2014AB	9	y
8	1913BD	9	y
9	2014BC	9	y
10	2014BB	9	y
11	1814CA	9	n
12	1914AC	9	y
13	2017CB	8	n
14	2014DD	9	y
15	2216AB	8	n
16	2015CA	9	y
17	2216AC	8	y
18	1913BA	9	y
19	2015DA	9	y
20	2115DD	8	y
21	1914AB	8	n
22	1914CB	9	y
23	2115BA	8	y
24	1713DA	8	y
25	1913BB	9	y
26	2116CC	8	y
27	2115BB	8	n
28	1914BC	8	n
29	1814CC	9	y
30	2017DC	8	n
31	1713AB	8	y
32	1813BB	8	n
33	1914CA	9	y
34	1813BA	8	y
35	1914CD	9	y
36	1613CC	8	y
37	1813AB	9	y
38	2115AC	8	y
39	2116CA	8	n
40	2215BD	8	y
41	2014AD	9	y
42	2116AA	7	n
43	2014DB	9	y
44	2116DD	7	n
45	2115BD	8	y
46	2014DA	9	y
47	1713AD	8	y
48	2116CD	8	n
49	2014DC	9	y
50	1713DD	9	n

Rank	QDS	No of species	RK ‡
51	1613CD	8	y
52	2015CB	9	y
53	2015DC	9	y
54	2215BC	8	y
55	2015CC	9	y
56	2115CD	8	y
57	2015DD	8	n
58	2215BA	8	y
59	2016AA	7	n
60	2014BA	9	y
61	2216AD	8	y
62	2116AD	7	n
63	1914DC	9	y
64	2115DB	8	y
65	2216AA	7	y
66	1713AC	9	y
67	2115DC	8	y
68	1713AA	8	y
69	2115CA	8	y
70	1714AC	8	n
71	2115AB	8	y
72	2316AA	8	y
73	1915CD	7	n
74	2114BA	9	y
75	2215DA	8	y
76	2015AC	7	y
77	2015AA	7	y
78	2017CA	7	n
79	2215DB	8	y
80	2115BC	8	y
81	2316AB	8	y
82	2116DA	7	n
83	2117CC	6	n
84	1713BD	8	n
85	2116BC	6	n
86	2016CB	6	n
87	1914BA	7	n
88	2016AD	6	n
89	1813BD	8	y
90	1913DB	9	y
91	2215BB	7	y
92	2115CB	8	y
93	2017CD	8	n
94	2116CB	8	n
95	2015AB	8	n
96	2014AC	9	y
97	2116AB	7	n
98	1914AA	6	y
99	1713CD	7	y
100	2016AC	6	n

Rank	QDS	No of species	RK ‡
101	2016DC	6	n
102	2015DB	9	n
103	2114DB	8	y
104	2217AC	6	n
105	2317BA	6	n
106	2014CD	9	y
107	2115AD	8	y
108	2216BD	6	n
109	1612DD	6	y
110	2015BD	8	n
111	2114BB	8	y
112	1913DD	9	y
113	1917CB	6	n
114	2216BA	7	n
115	1915AD	8	n
116	1713DC	6	y
117	2215AB	8	y
118	1917DC	6	n
119	2014CB	9	y
120	2115DA	7	y
121	2016CD	6	n

Rank	QDS	No of species	RK ‡
122	1714CC	7	n
123	1916DB	6	n
124	1917CA	6	n
125	1917AD	6	n
126	1915DB	7	n
127	1813CB	9	y
128	1814CB	6	n
129	2217DA	5	y
130	1914BD	6	n
131	1813CD	9	y
132	2216CD	7	y
133	2316AC	7	y
134	1713CB	7	y
135	1813AC	9	y
136	1814AD	6	n
137	1814DA	6	n
138	1914DD	8	n
139	2116AC	8	n
140	2217BD	6	n
141	1813BC	8	y
142	2015BA	6	n

† analysis was carried out using data from Hartlaub's francolin extrapolated across all potentially suitable areas, and thus the predicted number of species present in some squares may be an overestimate, however the ranking of QDS should not be significantly affected.

‡ Rüppell's korhaan predicted to occur within the QDS: Y yes; N no