

Geographical analysis of six rare bird species in the Kruger National Park, South Africa

J. L. HURFORD, A. T. LOMBARD, A. C. KEMP and G. A. BENN

Summary

Twenty-eight predominantly tropical bird species have ranges that only just extend into the north-eastern part of South Africa, mainly within the Kruger National Park (KNP). These species are listed as "rare" (<200 breeding pairs) in the South African Red Data Book (Brooke 1984). This study assesses the extent to which six of these rare bird species represent viable populations in the KNP. Grid squares in the KNP (2.5 × 2.5 miles) were visually assessed according to several bird habitat parameters. Bird records were also plotted on this grid system and habitat associations were identified for each species. This allowed for the measurement of total suitable habitat within the KNP for each species. Bird densities within known habitat were determined using spot-mapping and fixed-distance strip-transect techniques. Estimated population sizes for each species were obtained by extrapolating density estimates to total suitable habitat. Of the six study species, Arnot's Chat, Rudd's Apalis, Wattle-eyed Flycatcher and Tropical Boubou are likely to occur in sufficient numbers to constitute viable populations within the KNP, with estimated population sizes of 1,394, 4,758, 2,070 and 10,450 birds respectively. The populations of White-crowned Plover and Long-tailed Starling are probably too small to be viable in the long term, with estimated population sizes of 305 and 382 birds respectively. The results presented here are testable and can be used as a baseline for future monitoring.

Introduction

The Kruger National Park (KNP), situated in the north-eastern corner of South Africa (Figure 1), is the largest conserved region in the country and covers an area of approximately 20,000 km². Over 50% of the bird species in the South African Red Data Book (Brooke 1984) are reported to occur in the KNP. Some species are particularly dependent on the park for their existence as breeding species in South Africa. This highlights the importance of the KNP for the conservation of the country's rich avian biodiversity.

In recognition of the importance of the KNP for bird conservation in South Africa, a project was initiated to determine the viability of rare birds in the park. Two types of avian rarity are recognized in the KNP: (i) very large birds which have extensive spatial requirements and exist naturally at low densities; and (ii) small bird species that are rare simply because their ranges only just extend into the KNP, where their habitat is limited. The research reported here focuses on the latter. Within South Africa these small species occur mainly within the

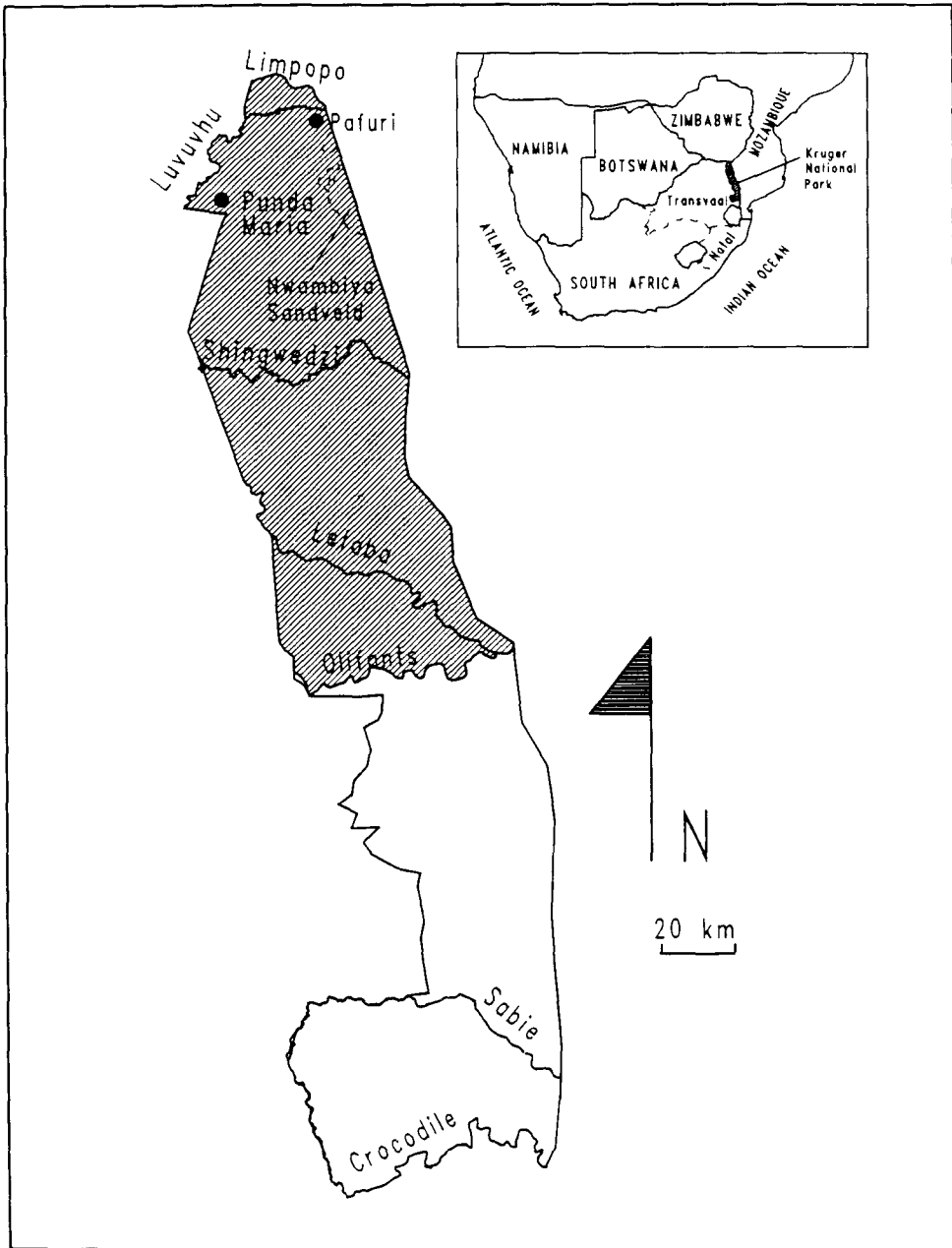


Figure 1. The KNP showing the study area (shaded region), major rivers and areas referred to in the text. The inset is a map of southern Africa indicating the position of the KNP, as well as the Transvaal and Natal provinces within South Africa.

Table 1. List of rare peripheral species reported to occur within the KNP.

	Common name	Scientific name
Category 1	Dwarf Bittern	<i>Ixobrychus sturmii</i>
	Bat Hawk	<i>Macheiramphus alcinus</i>
	Three-banded Courser	<i>Rhinoptilus cinctus</i>
	Red-winged Pratincole	<i>Glareola pratincola</i>
	Thick-billed Cuckoo	<i>Pachycoccyx audeberti</i>
	Black Coucal	<i>Centropus bengalensis</i>
	Pennant-winged Nightjar	<i>Macrodipteryx vexillaria</i>
	Racket-tailed Roller	<i>Coracias spatulata</i>
	Mosque Swallow	<i>Hirundo senegalensis</i>
	White-breasted Cuckoo-shrike	<i>Coracina pectoralis</i>
	Mashona Hyliota	<i>Hyliota australis</i>
	Yellow White-eye	<i>Zosterops senegalensis</i>
	Pink-throated Twinspot	<i>Hypargos margaritatus</i>
Lemon-breasted Canary	<i>Serinus citrinipectus</i>	
Category 2	Dark Chanting Goshawk	<i>Melierax metabates</i>
	Dickinson's Kestrel	<i>Falco dickinsoni</i>
	Crested Guineafowl	<i>Guttera pucherani</i>
	Mourning Dove	<i>Streptopelia decipiens</i>
	Cape Parrot	<i>Poicephalus robustus suahelicus</i>
	Mottled Spinetail	<i>Telacanthura ussheri</i>
	Boehm's Spinetail	<i>Neafrapus boehmi</i>
Yellow-billed Oxpecker	<i>Buphagus africanus</i>	
Category 3	White-crowned Plover	<i>Vanellus albiceps</i>
	Arnot's Chat	<i>Thamnolaea arnotti</i>
	Rudd's Apalis	<i>Apalis ruddi</i>
	Wattle-eyed Flycatcher	<i>Platysteira peltata</i>
	Tropical Boubou	<i>Laniarius aethiopicus</i>
Long-tailed Starling	<i>Lamprolornis mevesii</i>	

These species can be divided into three groups: small, eruptive species (category 1); small species with patchy habitat requirements (category 2); small species with specific and limited habitat requirements (category 3).

KNP (Kemp 1980) so that their maintenance in South Africa depends largely on the KNP. The South African Red Data Book for birds (Brooke 1984) lists 28 species that have rare (<200 breeding pairs), peripheral populations within the KNP and South Africa (Table 1). During our field study, it became apparent that these species could be further divided into three categories (Table 1): small, eruptive species that expand their ranges into the KNP only under certain conditions (category 1), small species with specific and patchy habitat requirements (category 2), and small species which require specific and contiguous limited habitat (category 3). The group of eruptive species (category 1) was found to be non-resident or too scarce to study. These species can be regarded as "spillovers" (Pulliam 1988, Stevens 1992) from a more productive neighbouring source and do not have viable populations in the KNP. Research on the viability of those species with specific and patchy habitat requirements (category 2) is still ongoing. This study evaluates the viability of species with specific and contiguous limited habitat (category 3). This necessitates (i) documenting the ranges of the study species within the KNP, (ii) identifying their habitat associations, (iii) assessing the availability of suitable habitat in the

KNP for each species, and (iv) determining their densities in suitable habitats and thus estimating their total numbers. It is intended that these data will serve as a baseline against which future populations can be monitored and conservation management planned.

Methods

Study area

Since the small rare species are mostly confined to the northern KNP, the study area comprised the KNP north of the Olifants River, an area of approximately 10,545 km² (Figure 1). The area is drained by three major river systems: the Olifants/Letaba, the Shingwedzi and the Limpopo/Luvuvhu. This area receives on average between 450 and 600 mm of rain a year, most of which falls between September and March (Gertenbach 1980). During the study period, however, the KNP suffered extreme drought with a 1991/92 summer rainfall as low as 52 mm recorded in the Pafuri region.

Data collection and analyses

Data were collected continuously over the two-year study period, from January 1991 to January 1993. Data were mapped according to the conventional grid system of 2.5 × 2.5 miles (~4 × 4 km) used by the National Parks Board for the KNP. The grid squares are further divided into quarters of 1.25 × 1.25 miles each (~2 × 2 km). The analyses for this study were completed using a Geographic Information System (GIS, ARC/INFO, version 3.4D+, Environmental Systems Research Institute, Redlands, California). Data layers of the KNP boundary, roads, rivers and camps were digitized off 1:50,000 topographical maps (Chief Directorate of Surveys and Land Information, South Africa).

Documenting species' ranges within the KNP

During the study period, an attempt was made to survey the entire study area, by vehicle or on foot, and record all sightings of study species on the 2 × 2 km grid. Additional information such as sex, age, nesting and immediate habitat was also recorded for each sighting where possible. The minimum geographic ranges of each study species were thus determined by plotting sightings of each species. This ensured that density estimates were not extrapolated to areas outside the known ranges of each species. Breeding and non-breeding distributions for the six study species are considered to be the same since they are described as sedentary (Maclean 1993).

Identifying species-habitat associations

Species-habitat assessments, encompassing a radius of 400 m (0.5 km²), were conducted for every study species sighting. The habitat parameters assessed included presence of water features, percentage open canopy, extent of ground

cover, and percentage woody vegetation (percentage tree, bush and scrub cover occupied by *Combretum* spp., *Terminalia* spp., *Mopane* spp., *Acacia* spp. and the riparian belt were specifically recorded). These habitat assessments, together with an *a priori* knowledge of each species's habitat preferences, were used as an aid to selecting habitat parameters important for each species. Only those habitat parameters considered important for each species were included in the search criteria used to extract available suitable habitat for each species.

Assessing availability of suitable habitat for each species

The extent of suitable habitat for each species was determined by visually assessing and mapping habitat parameters at the 4×4 km (16 km^2) grid scale. The habitat parameters assessed were the same as those in the species-habitat assessments. In order to identify all suitable habitat for a species, habitat assessments for grid squares (16 km^2) where that particular species was sighted during the study period were extracted from the database and frequency distributions of each habitat parameter considered important for that species were generated. These frequency distributions were then used to define search criteria. For example, if % tree cover is taken as being important for a particular species and the species has only been recorded in grid squares where % tree cover $>20\%$, then the search criterion for that species would be % tree cover $>20\%$. Using the search criteria (e.g. tree cover $>20\%$), all other grid squares qualifying as suitable within the range of each species were identified. Area of suitable habitat within a grid square was then calculated as the proportion of the grid square area occupied by the habitat parameter (e.g. tree cover) considered important for each species. For example, if tree cover is important for a species and within a particular grid square % tree cover = 30% , then the area of suitable habitat within that grid square was assumed to be 30% of the grid square area.

Density and population size estimation

For each species, number of birds within a specified transect area were calculated. Methods of censusing differed among species (Table 2). Observer bias (Verner 1985) was minimal because transects were conducted by the same observers (P. Chadwick, K. Begg, G. Benn), who were familiar with the study species. Bias resulting from differences in bird detectability was taken into account and width of transect was adjusted accordingly (Bibby *et al.* 1992). Differences in diurnal activity were recognized as a source of bias and transects were conducted only in the early morning or late afternoon to minimize diurnal bias (Verner 1985). Furthermore, search effort for each species was standardized and transects were not conducted in extreme weather conditions.

In order to estimate population sizes, bird densities were calculated using the transect techniques detailed in Table 2. Densities were then extrapolated to the total area of suitable habitat for each species. Two different methods were used to obtain density estimates from transect data:

(i) The spot-mapping method was employed to estimate the density of all species except the Long-tailed Starling. Spot-mapping is a procedure that plots,

Table 2. List of transect techniques used to determine density estimates for the study species.

Species	Transect dates	Transect technique
White-crowned Plover	April to September 1991 and 1992	Walked transects along the Luvuvhu River were conducted. In 1991, breeding territories were determined along the Luvuvhu River. A walk along the Olifants River was conducted in 1992. Annual aerial hippopotamus surveys conducted by the National Parks board were used to estimate population size in the southern KNP.
Amot's Chat	January to February 1991 and 1992	Two transects of 6 km long in the vicinity of Punda Maria were conducted during the breeding season when birds remain within exclusive territories and are most likely to respond to taped calls. Taped calls were played every 200 m for 5 minutes and responses/sightings within 200 m either side of the transect line were noted.
Rudd's Apalis	January to February 1991 and 1992	Two transects of ± 2 km parallel to the eastern border fence in Nwambiya Sandveld habitat were surveyed during the breeding season when the birds are most likely to respond to taped calls. Taped calls were played every 80 m for 5 minutes and responses/sightings within 200 m either side of the transect line were noted.
Wattle-eyed Flycatcher	September 1990 to April 1991, January 1992	An 8 km stretch of the Luvuvhu River was walked 41 times recording sightings/vocalizations of birds within 50 m on either side of the river (i.e. a total area of 0.8 km ²).
Tropical Boubou	September 1990 to April 1991, January 1992	An 8 km stretch of the Luvuvhu River was walked 41 times in conjunction with Wattle-eyed Flycatcher transects. Sightings/vocalizations of birds within 200 m on either side of the river (i.e. a total area of 3.2 km ²) were recorded.
Long-tailed Starling	Throughout 1991 and 1992	Two road transects, one on the north bank of the Luvuvhu River (12 km in length) and one on the south bank of the Luvuvhu River (15–16 km), were driven at regular intervals. Bird sightings and vocalizations within 100 m of either side of the road were recorded.

on a map, cumulative number of bird territories after several visits to the area. "Clusters" of locations are identified and assumed to represent centres of activity by territory holders (Edwards *et al.* 1981, Franzreb 1981, Verner 1985). This method is appropriate for estimating densities of cryptic bird species since the area is visited several times, thus providing opportunity to discover all, or most, territories in the area. However, the method is fairly inflexible in that it is usually restricted to certain times of year when the birds are breeding and therefore remain within confined territories. Moreover, no margin of error can be placed on the density estimate derived (Bibby *et al.* 1992).

(ii) The fixed-distance strip-transect method was employed to estimate density of the non-territorial Long-tailed Starling. This involves counting all birds within a fixed width of a strip of land and dividing this number by the area of the transect to obtain density (Verner 1985). This method differs from spot-mapping in that densities are calculated from mean number of birds, instead of cumulative number of birds, per transect. Since mean density is calculated from replicate samples, a margin of error can be placed on the density estimate derived. This method of density estimation is best for conspicuous and/or vocal species, since it relies on the assumption that all birds present within the transect area are detected. However, densities of the smaller, more cryptic bird species tend to be underestimated, because it is unlikely that all individuals within the transect area are detected per transect.

For cryptic species, the spot-mapping method of estimating density is preferable even though no margin of error can be placed on the estimate. Spot-mapping also provides a useful index with which to calibrate future, more flexible fixed-distance strip-transects. By comparing the total number of territories discovered by spot-mapping (e.g. 100) with the mean number of territories discovered per transect (e.g. 50), a calibration factor (in this case 50%) can be derived with which to calibrate future fixed-distance strip-transects.

Results

Measurement of available suitable habitat and the importance of scale

The habitat assessments within a 400 m radius of a species (0.5 km²) gave an indication as to which habitat parameters were important for each bird species. They also drew attention to a scale-related problem in the measurement of extent of suitable habitat for some species. The resolution of the grid square habitat assessments (16 km²) greatly exceeds the potential territory size of all study species. At the coarser 4 × 4 km scale, habitat is relatively homogeneous (neighbouring grid squares are similar), but within the grid square at a scale relevant to the study species the habitat was found to be heterogeneous. Measuring the extent of suitable habitat using the grid square habitat assessments will, therefore, not produce accurate results. Scale problems such as these are prevalent in studies which predict species distributions based on habitat distributions and preferences (Turner *et al.* 1989, Stoms 1992, 1994) where trade-offs exist between mapping effort and habitat detail. The scale-related problem in this study can be illustrated by the following example. The Long-tailed Starling is found in 4 × 4 km grid squares where bare ground

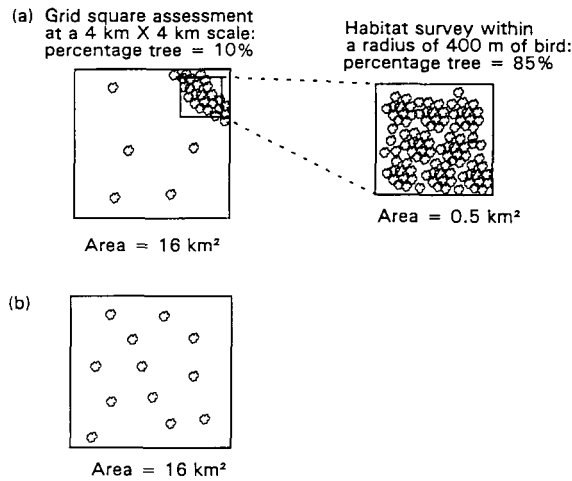


Figure 2. (a) Schematic representation of habitat heterogeneity within a 4×4 km grid square. (b) A 4×4 km grid square in which trees are present in the same proportion as (a), but are dispersed differently. For a bird seeking dense woodland, only the dense tree habitat in (a) is suitable.

is $>50\%$ and % tree cover $>10\%$. The % tree cover is surprisingly low, considering that habitat assessments within a 400 m radius of a bird sighting document this species in areas where % tree cover is most often between 30 and 40%. This problem arises because of differences in scale (Figure 2a). It is clear from Figure 2a that extrapolating Long-tailed Starling density to the entire area of the grid square (16 km^2) would grossly overestimate population size, since suitable tree habitat for Long-tailed Starlings occurs only in 0.5 km^2 of the area. This problem was resolved by measuring suitable habitat for a species as the percentage of grid square area occupied by the habitat parameter deemed important for that species, rather than using the entire grid square area. Nevertheless, distribution of habitat within the grid square is also important and less easily resolved. Figure 2b shows a grid square in which trees are present in the same proportion as in Figure 2a, but are distributed differently. There is a patch of potentially suitable habitat for Long-tailed Starlings in Figure 2a. However, the distribution of trees is so scattered in Figure 2b that none of the habitat can be regarded as suitable for this species.

Extrapolating density estimates across these widely differing scales is not serious for the riparian study species, for example the Wattle-eyed Flycatcher and Tropical Boubou, because the riparian belt within a grid square is clumped. The problem of scale is more applicable to species whose habitat is scattered within the grid square, for example, Arnot's Chat, Rudd's Apalis and Long-tailed Starling.

Population sizes

White-crowned Plover *Vanellus albiceps* In South Africa, Maclean (1993) reports White-crowned Plovers outside the KNP along the Limpopo River only (Figure

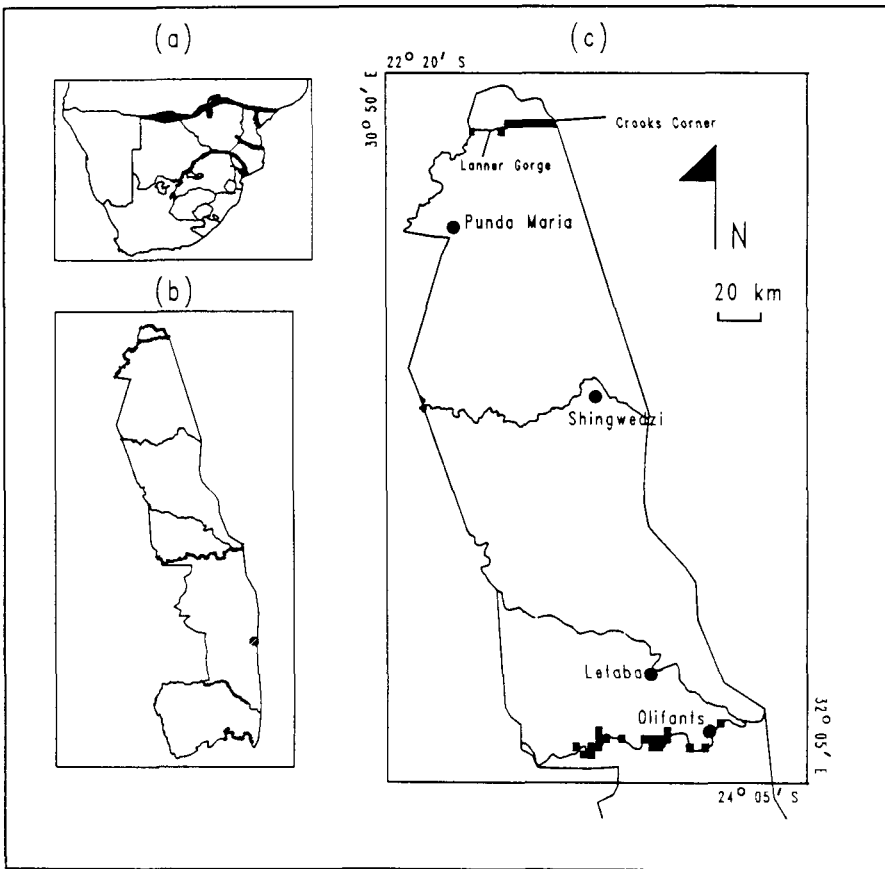


Figure 3. Distribution (shaded areas) of the White-crowned Plover (a) in southern Africa (after Maclean 1993) and (b) in the entire KNP (after Sinclair and Whyte 1991). Grid squares (2×2 km) where this species was recorded during the study period are shown in (c).

3a). Sinclair and Whyte (1991) report a few scattered records in the southern KNP along the Sabie and Crocodile Rivers (Figure 3b), but the majority of the population is restricted to the Luvuvhu and Olifants Rivers in the northern KNP (Figures 3b and 3c). Each year the KNP staff conduct a helicopter survey along the major rivers specifically to count hippopotamus. Other riverine species are also counted, including the White-crowned Plover. From these surveys, it appears that 98% of the White-crowned Plover population occurs in the northern KNP (Table 3). Thus, our habitat assessments were conducted in the northern KNP only and, using the annual aerial counts, were extrapolated to include the southern KNP population.

Suitable breeding habitat for the White-crowned Plover includes river sandbanks adjoining water (Maclean 1993), which occurs along the Luvuvhu (85.5 km) and Olifants (99.8 km) Rivers in the northern KNP. Continuous stretches of suitable habitat occur along the stretch of Luvuvhu River from just before Lanner Gorge to Crook's Corner (see Figure 3c for locations), a length

Table 3. White-crowned Plover counts from the annual hippopotamus survey conducted by the National Parks Board.

	River system	Mean number of birds \pm standard error ($n = 6$)	Total number of birds
Northern KNP:	Limpopo/Luvuvhu	47.7 \pm 22.8	180.6
	Shingwedzi	0.0 \pm 0.0	
	Letaba	0.2 \pm 0.4	
	Olifants	132.7 \pm 53.0	
Southern KNP:	Sabie	2.7 \pm 1.8	3.9
	Crocodile	1.2 \pm 1.8	

Ratio northern : southern KNP = 98:2

The mean number of birds is a mean of survey results from 1987–1992 (i.e. $n = 6$).

of 19 km. During the 1991 breeding season (early summer, mainly October) this area supported 33 breeding pairs, representing a density of 1.74 pairs/km of river. The remaining stretch of Luvuvhu River west of Lanner Gorge and along the western border of the KNP (66.5 km) is more rocky, has fewer sandbars and is less favourable. The habitat along the entire stretch of the Olifants River is most similar to the less suitable habitat of the Luvuvhu River. Nineteen less suitable stretches, totalling 70.4 km, along the entire length of the Olifants River surveyed in March 1992 supported 100 birds (1.42 birds/km of river). By extrapolation, the less suitable Olifants and Luvuvhu River habitat can be calculated to support 142 and 94 birds respectively. Thus, the population of White-crowned Plover in the northern KNP is approximately $66 + 142 + 94 = 302$ birds (Table 4).

To obtain an index with which to calibrate future fixed-distance strip-transects, densities per transect (Table 2) were pooled. Mean density per transect and standard error were calculated as 1.65 ± 0.06 pairs/km in suitable habitat ($n = 3$) and 1.53 ± 0.33 birds/km in less suitable habitat ($n = 19$), which are similar to the respective densities estimated using the spot-mapping method. White-crowned Plovers are fairly conspicuous birds and, therefore, densities estimated using the fixed-distance strip-transect method do not need to be calibrated, and a margin of error can be calculated for the estimate.

Extrapolating our results to the southern KNP (using the ratio calculated in Table 3) yields a total KNP population of White-crowned Plovers of approximately 308 birds. The annual aerial hippopotamus counts for White-crowned Plover in the northern KNP (Table 3) are lower than our river walk counts (Table 4), although still within the same order of magnitude. This was expected, since our walks concentrate solely on White-crowned Plover, which are also easier to spot on the ground.

Arnot's Chat *Thamnolaea arnoti* In South Africa, Maclean (1993) reports Arnot's Chat outside the KNP in the extreme north-eastern Transvaal (Figure 4a). Within the KNP, this species occurs mainly in the north (Figure 4b), and species-habitat surveys record them wherever areas of tall mopane forest with a closed understorey exist. Thus, the % mopane tree cover in combination with the % bush cover were considered important habitat parameters for Arnot's

Table 4. Viability assessment of the study species.

Species	Population size		Breeding records	Viability	Notes
	S-M	F-D			
White-crowned Plover	302 ^a	317; <i>n</i> = 3 (208–426)	clutch size (mean = 3.3 eggs; <i>n</i> = 8) as large as that closer to core range (Urban <i>et al.</i> 1986)	Viability unlikely	Although there is evidence of successful breeding, the population size is probably too small to ensure long-term viability within the KNP. Contiguous South African and Mozambican populations are likely to maintain KNP populations.
Arnott's Chat	1,394	877; <i>n</i> = 5 (252–1,502)	1 confirmed nest in hollow of mopane tree; 6 juvenile sightings	Potentially viable	Contiguous populations exist outside the KNP in South Africa, Zimbabwe, Botswana and Mozambique.
Rudd's Apalis	4,758	1,465; <i>n</i> = 9 (1,035–1,895)	None, nests difficult to detect	Potentially viable	Transects are conducted close to the eastern KNP fence, along the Mozambique border. It is likely that the KNP population is sustained by the Mozambican population. Contiguous South African populations exist outside the KNP in the Natal province.
Wattle-eyed Flycatcher	2,070	101; <i>n</i> = 41 (46–147)	None, nests difficult to detect	Potentially viable	Contiguous South African and Mozambican populations exist outside the KNP.
Tropical Boubou	10,450	2,216; <i>n</i> = 41 (1,852–2,580)	None, nests difficult to detect	Potentially viable	Density in non-riparian habitat is unlikely to be as high as density in riparian habitat, which may lead to overestimation of population sizes. Contiguous populations exist outside the KNP in South Africa, Zimbabwe, Botswana and Mozambique.
Long-tailed Starling	—	382; <i>n</i> = 32; (281–483)	Two nests recorded (Feb 1991) in fever tree (<i>Acacia xanthophloea</i>) hollows	Viability unlikely	The population size may be an underestimate since birds deeper into the transect may not have been detected. This problem may not be too serious for the Long-tailed Starling with its distinctive loud song. Contiguous populations exist outside the KNP in South Africa, Zimbabwe and Mozambique.

Population sizes are calculated from both the spot-mapping method (S-M) as well as the fixed-distance strip-transect method (F-D), range = mean ± 95% confidence limits, calculated as population mean ± (population standard error × 1.96) according to the Central Limit Theorem (Fowler and Cohen undated, >1983).

^a An estimated total population size of 308 birds when the annual aerial hippopotamus surveys are included (see text for explanation).

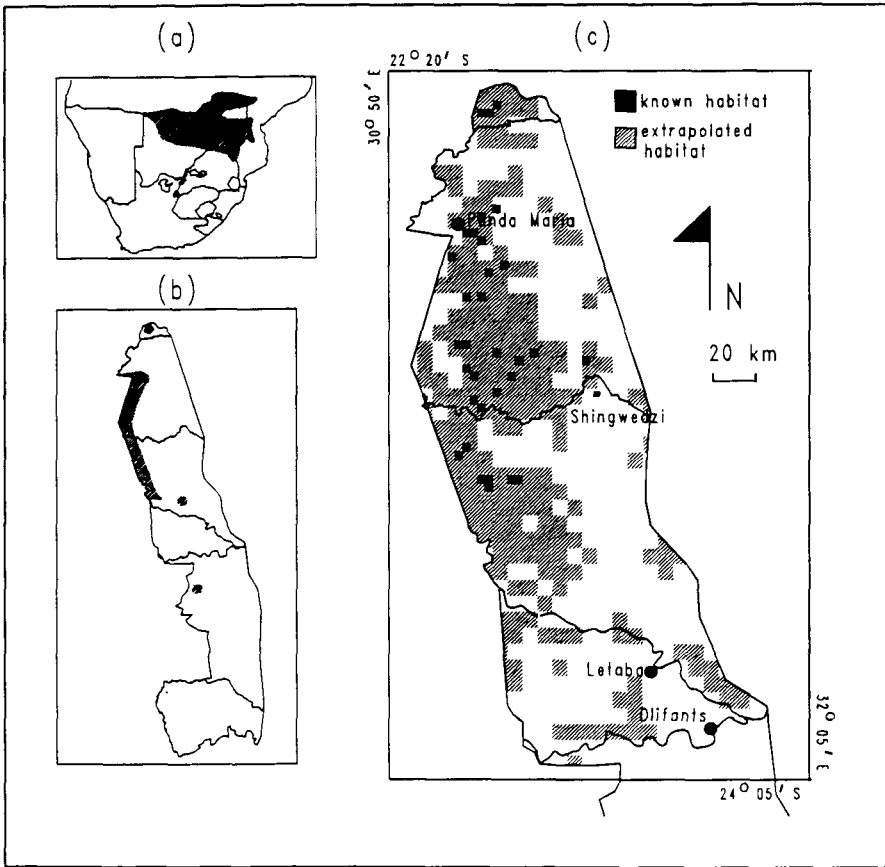


Figure 4. Distribution of Arnot's Chat (a) in southern Africa (after Maclean 1993) and (b) in the entire KNP (after Sinclair and Whyte 1991). Grid squares (2×2 km) where this species was recorded during the study period (known habitat) and distribution of suitable habitat (extrapolated habitat) are shown in (c).

Chat. Birds were recorded only in grid squares where % mopane tree cover $\geq 10\%$ and % bush cover $\geq 25\%$, a total area of 498 km² (Figure 4c).

Spot-mapping of the transect data during the breeding season (Table 2) found a total of 7 pairs in an area of 5.0 km², yielding a density estimate of 2.80 birds/km². Extrapolating this density estimate to all suitable habitat, a total population size of 1,394 birds within the KNP is obtained (Table 4).

To obtain an index with which to calibrate future fixed-distance strip-transects, densities per transect (Table 2) were pooled and mean density and standard error were calculated (1.76 ± 0.64 birds/km²; $n = 5$). Extrapolating this density estimate to suitable habitat yields a population size that is 63% of the population size obtained using the spot-mapping method (Table 4).

Rudd's Apalis *Apalis ruddi* In South Africa, Maclean (1993) records this species in northern Natal (Figure 5a). Our study found this species to be extremely localized within the KNP (Figure 5b) and, according to the species-habitat surveys, restricted to dense, tangled thickets in the Nwambiya Sandveld area

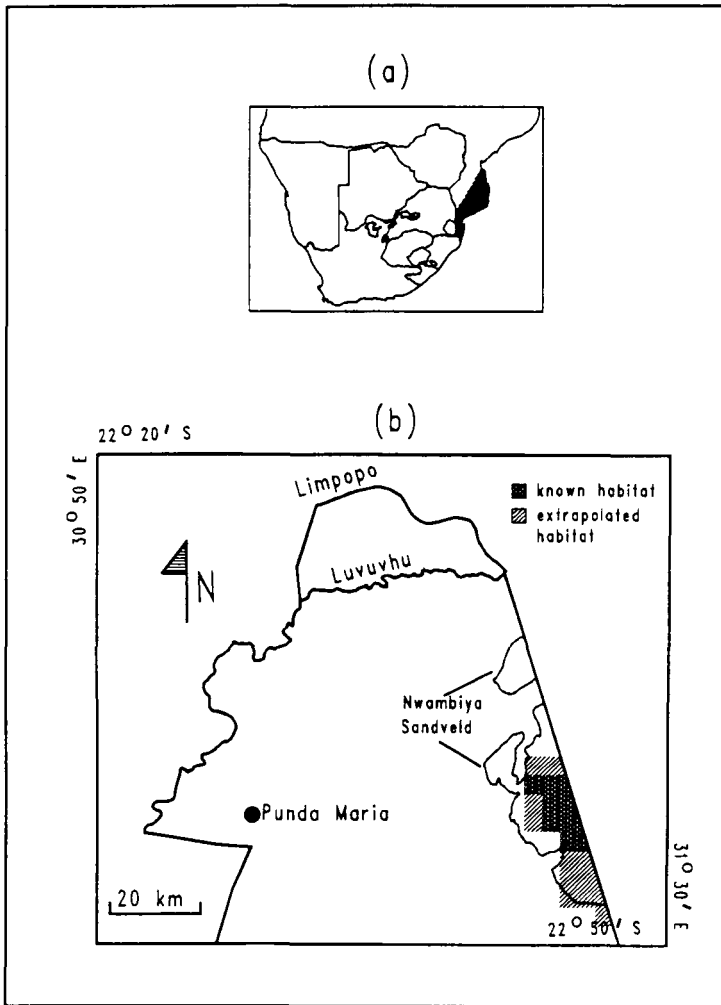


Figure 5. Distribution of Rudd's Apalis (a) in southern Africa (after Maclean 1993). Grid squares (2×2 km) where this species was recorded during the study period (known habitat) and distribution of suitable habitat (extrapolated habitat) are shown in (b). Sinclair and Whyte (1991) do not record Rudd's Apalis in the KNP.

(see Figure 1 for location). Rudd's Apalis was recorded only in grid squares with more than 60% bush cover. Thus, all grid squares in the Nwambiya Sandveld region with % bush $\geq 60\%$ were considered suitable for Rudd's Apalis, a total area of 97 km² (Figure 5b).

Spot-mapping of the data collected on transects during the breeding season (Table 2) found a total of 52 birds (assuming that each "cluster" represents a pair of birds) in an area of 1.06 km², yielding a density estimate of 49.06 birds/km². Extrapolating this density estimate to all suitable habitat, a total population size of 4,758 birds within the KNP is obtained (Table 4).

To obtain an index with which to calibrate future fixed-distance strip-transects, densities per transect (Table 2) were pooled and mean density and standard error were calculated (15.10 ± 2.26 birds/km²; $n = 9$).

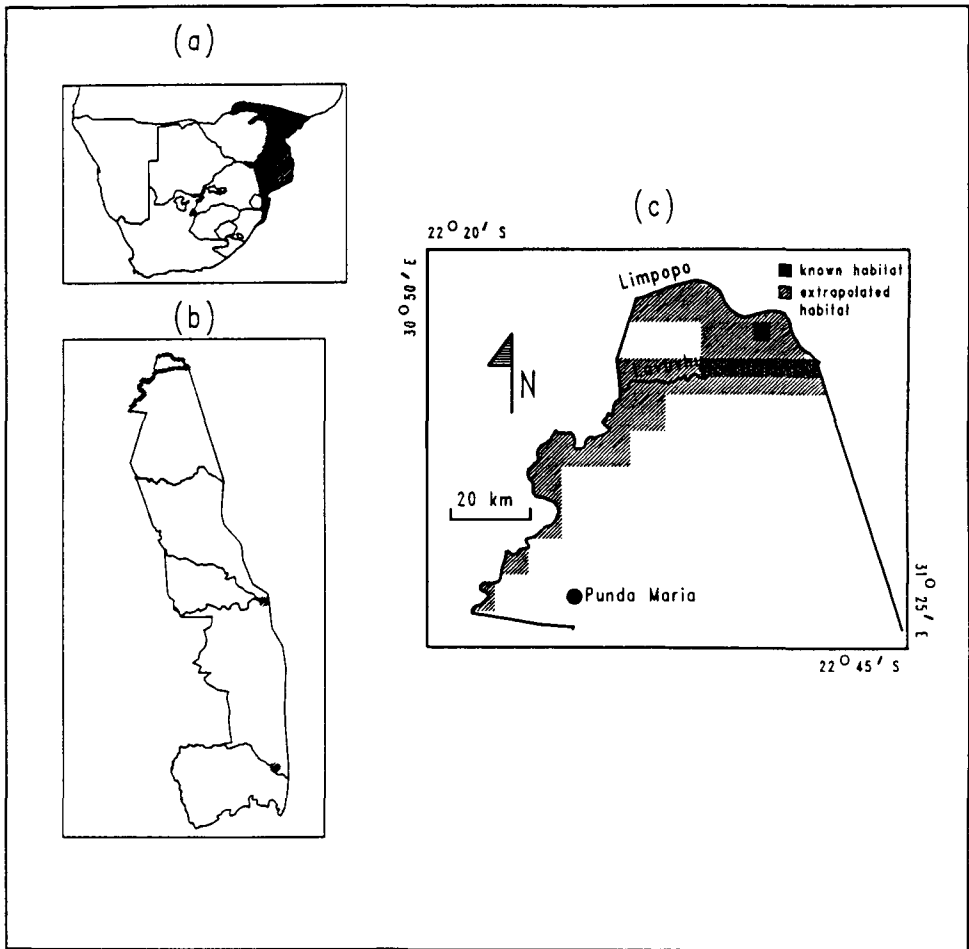


Figure 6. Distribution of Wattle-eyed Flycatcher (a) in southern Africa (after Maclean 1993) and (b) in the entire KNP (after Sinclair and Whyte 1991). Grid squares (2×2 km) where this species was recorded during the study period (known habitat) and distribution of suitable habitat (extrapolated habitat) are shown in (c).

Extrapolating to suitable habitat yields a population size that is only 31% of the population size obtained using the spot-mapping method (Table 4).

Wattle-eyed Flycatcher *Platysteira peltata* In South Africa, Maclean (1993) records this species outside the KNP in both the north-eastern Transvaal and in the Natal province (Figure 6a). Sinclair and Whyte (1991) report a few scattered records on the Olifants and Sabie Rivers (Figure 6b), but the main population occurs in the northern KNP in dense riverine thickets along the Limpopo and Luvuvhu Rivers (Figure 6b,c). The area of suitable habitat along these rivers represents an area of 46 km² (Figure 6c).

Spot-mapping of the transect data (Table 2) yielded a total of 18 territories along the area of Luvuvhu River surveyed (0.8 km²). Each territory was assumed

to represent a breeding pair; therefore, a total of 36 birds occurred within the area surveyed and density was calculated as 45.00 birds/km². Extrapolating to all suitable habitat gives a maximum population size of 2,070 birds within the KNP (Table 4).

To obtain an index with which to calibrate future fixed-distance strip-transects, densities per transect (Table 2) were pooled and mean density and standard error were calculated (2.21 ± 0.61 birds/km²; $n = 41$). Extrapolating to suitable habitat yields a population size that is only 5% of the population size obtained using the spot-mapping method (Table 4). Since the Wattle-eyed Flycatcher is difficult to detect in its dense bush habitat, it is unlikely that all individuals within the area are detected per transect. Future fixed-distance strip-transects should take this into account.

Tropical Boubou *Laniarius aethiopicus* In South Africa, Maclean (1993) reports this species outside the KNP along the Limpopo River (Figure 7a). Within the KNP, this species is restricted to the north (Figure 7b) and occurs most often in the riparian forests of the Limpopo/Luvuvhu valley (Sinclair and Whyte 1991), but species-habitat surveys also report it in any dense thickets of bush and trees north of Punda Maria (Figure 7c). Its southernmost boundary in the KNP is Punda Maria, and all suitable habitat north of this boundary, except for habitat in the Nwambiya Sandveld area (see Figure 1 for location), was assumed to be occupied. Grid squares north of the southern boundary where the combined percentage of tree and bush cover (T + B) is more than 65% (258 km²) were regarded as suitable habitat (Figure 7c), as well as any grid squares with riparian vegetation (46 km²). Censusing of this species was confined to riparian habitat and the density thus obtained was assumed to be the same in non-riparian habitat. However, density within the riparian habitat is likely to be higher than in the non-riparian habitat, so that the estimated population size may be an overestimate.

Spot-mapping of transect data yielded a total of 55 territories along the area of Luvuvhu River surveyed (3.2 km²). Each territory was assumed to represent a breeding pair, hence a total of 110 birds occur within the area surveyed and density was calculated as 34.38 birds/km². Extrapolating this density to the area occupied by riparian vegetation (46 km²) gives a riparian population size of 1,581 birds. Assuming the same density of Tropical Boubous in thickets away from rivers (i.e. where T + B >65%), the non-riparian population size is estimated to be 8,869 birds. Total population size is, thus, estimated to be approximately 10,450 birds (Table 4).

Extrapolating the mean density per transect and standard error (7.29 ± 0.61 birds/km²; $n = 40$) to suitable habitat yields a population size that is only 21% of the population size obtained using the spot-mapping method (Table 4).

Long-tailed Starling *Lamprotornis mevesii* In South Africa, Maclean (1993) reports this species outside the KNP along the Limpopo River (Figure 8a). Within the KNP, Long-tailed Starlings occur only in the Limpopo/Luvuvhu valley (Figure 8b). Sightings further south require confirmation (Tarboton *et al.* 1987) since this bird is often confused with Burchell's Starling *L. australis*.

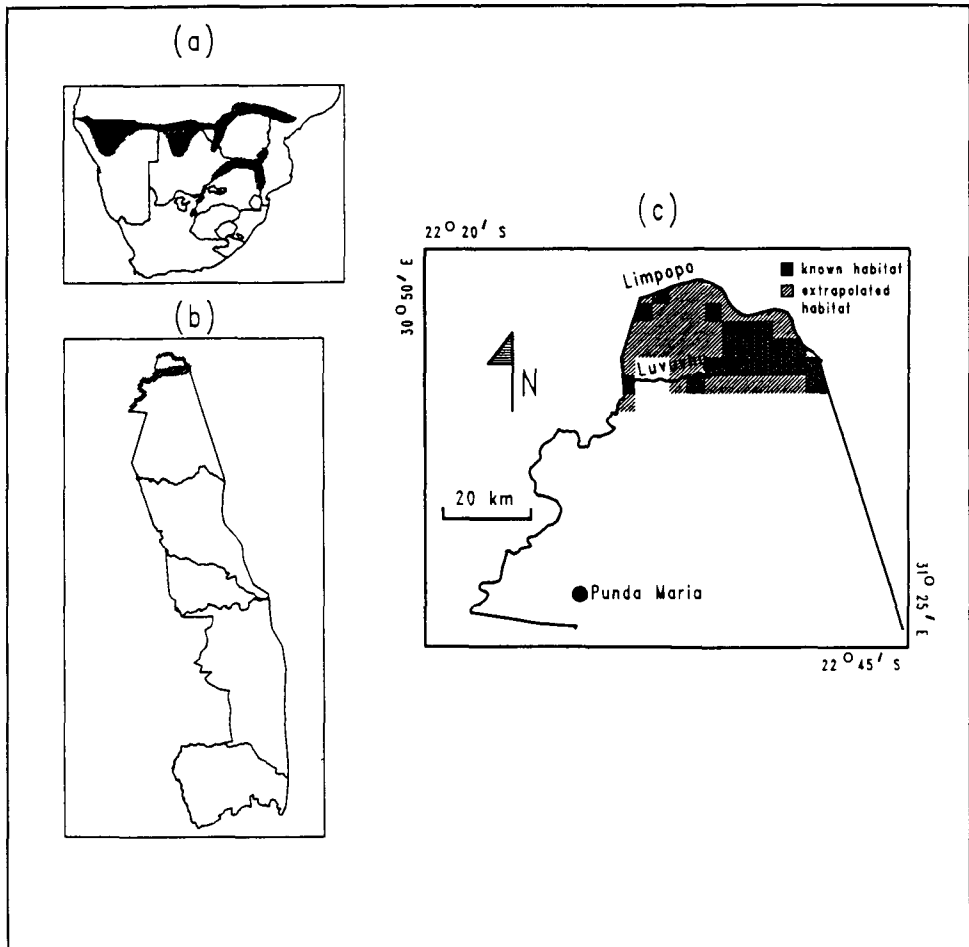


Figure 7. Distribution of Tropical Boubou (a) in southern Africa (after Maclean 1993) and (b) in the entire KNP (after Sinclair and Whyte 1991). Grid squares (2×2 km) where this species was recorded during the study period (known habitat) and distribution of suitable habitat (extrapolated habitat) are shown in (c).

Long-tailed Starlings favour open woodland with bare ground (where they forage for fruit and insects) and tree-hollows for breeding (Maclean 1993). Thus, extent of bare ground and of % tree cover were considered important habitat parameters for Long-tailed Starlings, which occur only where bare ground $> 50\%$ and % tree cover $> 10\%$. Using these search criteria all grid squares with habitat suitable for Long-tailed Starlings were located (Figure 8c). The areas of trees within these grid squares represent a total area of 61 km^2 .

Densities obtained for both transects (Table 2) were compared and were not significantly different (Mann–Whitney U-test). Thus, the data were pooled and mean density and standard error were calculated as 6.26 ± 0.84 birds/ km^2 . Extrapolating this to the area of suitable habitat (61 km^2) yields a total population size of 382 birds in the KNP (lower and upper 95% confidence limits are 281 and 483 respectively).

populations are treated as isolated from contiguous unprotected populations outside the park. Currently, it is likely that many KNP populations are maintained by these contiguous unprotected populations. In the event of these contiguous unprotected populations persisting, a KNP population of less than 1,000 adults may even be viable.

Discussion

Management options

Conservation priorities at regional, national and global levels differ, and management options will depend critically on the scale and goals of the conservation effort (Peterson *et al.* 1993). Management options discussed below therefore consider conservation of the study species at a regional level (within the KNP) as well as conservation at a national and global level.

Conservation in the KNP

According to this study, Arnot's Chat, Rudd's Apalis, Wattle-eyed Flycatcher and Tropical Boubou have population sizes large enough to be potentially viable within the KNP. However, the KNP populations of White-crowned Plover and Long-tailed Starling are probably too small to be viable in the long term. Management of all these study species should be viewed at a national level, since many populations that are deemed not viable within the KNP may be viable when other populations within South Africa are taken into account.

For conservation of these species, it is better to concentrate management efforts on bird habitats, rather than on the protection of specific species. The density data and bird-habitat association data collected in this study may serve as baseline material for future monitoring of populations in the KNP. When the areas of suitable habitat identified for each species are combined, it is apparent that the Luvuvhu/Limpopo as well as the Olifants River systems are particularly important for a number of species. The White-crowned Plover, Tropical Boubou and Wattle-eyed Flycatcher assessed in this study are all associated with such riparian habitat. Furthermore, the habitat in the Punda/Pafuri region is of prime importance to Arnot's Chat, Tropical Boubou and Long-tailed Starling.

Conservation at a national level

The conservation of the study species in South Africa should be seen in the light of metapopulation conservation (Hanski 1991), particularly given that birds are generally vagile creatures, able to move between populations more easily than many other vertebrates. Movement between populations is likely to play an important role in population dynamics and lowers the risk of extinction. The White-crowned Plover and Long-tailed Starling may not be viable within the KNP. However, these species have contiguous populations outside the KNP, extending into the Natal and/or Transvaal provinces (Figures 3a and 8a, respectively). Thus, the KNP populations may be important to the overall

viability within South Africa even though they themselves do not represent viable populations.

Conservation at a global level

Rare species are often threatened with extinction, thus conservation priority is often given to rare species. The species of this study are listed as "rare" in the South African Red Data Book (Brooke 1984) simply because their ranges just extend into South Africa from further north where they are more widespread (Hall and Moreau 1970, Snow 1978). At a global scale, it therefore seems less important to assign conservation priority to these species purely because of a political boundary. From a global viewpoint, the White-crowned Plover, Arnot's Chat, Tropical Boubou and Long-tailed Starling (Figures 3a, 4a, 7a and 8a, respectively) also gain protection in Botswana and Zimbabwe, closer to the centre of their ranges. Considering that the level of conservation in Botswana and Zimbabwe is comparable to the level in South Africa, these species are relatively well protected. However, Rudd's Apalis and the Wattle-eyed Flycatcher should receive higher global conservation priority, since their ranges within southern Africa are mainly confined to Mozambique (Figures 5a and 6a, respectively) where civil war and political instability has led to the breakdown of protection measures within the country's national parks and reserves (Stuart and Adams 1990).

Conclusions

The results of this study should be viewed within the limits of several factors. These include problems related to habitat scale and problems inherent to censusing cryptic species. Furthermore, given that the KNP ranges for the study species were based on recorded sightings, and thus represent minimum geographic ranges, the population sizes may be underestimated. Moreover, the severe drought in the KNP during the survey may have led to further underestimation of population sizes particularly for the White-crowned Plover, which requires stretches of sandbars next to water for breeding. Nevertheless, the results give conservative estimates of population sizes which can be used as management guidelines and as a baseline against which future population trends can be monitored. However, prior to monitoring, the accuracy of the technique used to predict suitable habitat should be tested. This can be done by visiting grid squares predicted to have suitable habitat for a species and confirming the presence of that species. Thereafter, randomized fixed-distance strip-transects within areas of suitable habitat can be conducted, using the calibration factor calculated from the spot-mapping method in this study.

The KNP, with its high degree of habitat management and protection, has the potential of making a significant contribution toward the conservation of the study species, particularly those that are likely to be viable within the park. Populations not considered viable within the KNP should not be disregarded because, combined with contiguous populations outside the park, they may be viable at a national and global level.

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J. L. HURFORD, A. T. LOMBARD and G. A. BENN

Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch, 7700, South Africa

A. C. KEMP

Transvaal Museum, P.O. Box 413, Pretoria, 0001, South Africa