

A first estimate of the population size of Loveridge's Sunbird *Nectarinia loveridgei*, endemic to the Uluguru Mountains, Tanzania

ANDERS P. TØTTRUP, JØRN LENNART LARSEN and NEIL D. BURGESS

Summary

The Eastern Arc Mountains of East Africa are known for an exceptionally rich flora and fauna with very high endemism. For the conservation of rare forest birds these mountains are of the utmost importance in Africa. We provide the first population estimate of the endemic Loveridge's Sunbird *Nectarinia loveridgei* in the Uluguru Mountains of eastern Tanzania. Our study was conducted between September and December 2000. Capture-recapture using mistnets was used to gather data at eleven study sites between 1,300–2,600 m altitude in four different areas on the Ulugurus. The program CAPTURE was used to estimate the population at each study site. Since the home range of Loveridge's Sunbird is unknown, the density of the potential population was calculated by assuming home ranges ranging from 0 km² through to 3 km². When combined with data on the forest area in the Ulugurus and fixing the lower and upper home range sizes for this species at 0.1 km² and 0.8 km², we obtain an estimated total population ranging from 21,000 to 166,000 individuals. A median home range of 0.45 km² estimates the population close to 37,000 individuals. The species does not seem threatened but its long-term survival will depend on the survival of the forest, and in particular on how well the forest reserves on the Ulugurus are managed in the future.

Introduction

The Uluguru Mountains (6°43'–7°15'S 37°32'–51'E) are part of the ancient crystalline mountain chain called the Eastern Arc Mountains that runs from the Taita Hills in southeast Kenya, to the Makombako Gap southwest of the Udzungwa Mountains in Tanzania (Lovett and Wasser 1993). The Eastern Arc Mountains have an exceptionally rich flora and fauna with very high endemism (e.g. Scharff *et al.* 1982, Collar and Stuart 1988, Lovett 1988, Lovett and Wasser 1993, Burgess *et al.* 1998, Myers *et al.* 2000). The Uluguru Mountains hold two strictly endemic bird species and 12 that are range-restricted. Of these 14 species, six are globally threatened (Stattersfield *et al.* 1998, BirdLife International 2000).

Within Tanzania, the numbers of endemic and near-endemic bird species in the Uluguru Mountains are surpassed only in the Usambara and Udzungwa Mountains. Hence, the Uluguru Mountains are of extremely high conservation value and have been determined as the 16th most important area in Africa and the fourth most important area in East Africa for the conservation of rare

forest birds (Collar and Stuart 1988). They are also an African priority for the conservation of vertebrate species (Burgess *et al.* 1998, Brooks *et al.* 2001).

The avifauna of the Uluguru Mountains has been described by Stuart and Jensen (1985) (see also Stuart *et al.* 1993) and by the “Uluguru Biodiversity Survey 1993” (Svendsen and Hansen 1995). However, none of these studies were able to provide a quantitative measure of the abundance of the two endemic bird species in these mountains. In this paper we report on a first estimate of the population size of one of the endemic birds, Loveridge’s Sunbird *Nectarinia loveridgei* (Hartert, 1922). This study forms a part of the Uluguru Mountains Biodiversity Conservation Project, a conservation and development project managed by BirdLife Denmark (Dansk Ornitologisk Forening) and BirdLife Tanzania (Wildlife Conservation Society of Tanzania). A population estimate for the other Uluguru endemic bird species, Uluguru Bush-shrike *Malaconotus alius*, is reported elsewhere (Burgess *et al.* 2001, Romdal and Rahner in prep.).

Study sites and methods

Our study was conducted between September and December 2000 in four principal areas in the Uluguru forests (Figure 1). We investigated both of the two large forest reserves in the mountains, Uluguru South and Uluguru North and also spent some time in several of the smaller reserves (see Burgess *et al.* 2002 for details). The study sites ranged from 1,300 to 2,600 m a.s.l., in the submontane, montane and upper montane forest zones (Pócs 1976). The submontane forest between 800 and 1,500 m is the most luxuriant part of the forest with a canopy height of 30–60 m heavily laden with epiphytes (Pócs 1976a,b). This habitat has been cleared around the Uluguru South Forest Reserve, where the lower forest boundary in the southwest has been pushed up to almost 2,000 m, but remains in the Uluguru North Forest Reserve and some surrounding areas. Within the Uluguru North Forest Reserve, and on village land outside this reserve, significant areas of submontane forest at 800–1,500 m remained in the early 1990s (Lovett and Pócs 1993), and there were small pockets of riparian forest as low as 600 m (Lovett *et al.* 1995). Most of this lower altitude forest has since been cleared (Burgess *et al.* 2002). Montane forest occurs between 1,500 and 2,400 m with a canopy height of 15–40 m. Upper montane forest is found above 1,900 m with subalpine elfin forest growing on the highest peaks where trees and shrubs only reach a height of 3–6 m (Pócs 1976a,b). Both montane and upper montane forests are found in Uluguru North and South Forest Reserves.

Former fieldwork has shown that Loveridge’s Sunbird is highly mobile and difficult to census (Svendsen and Hansen 1995). We therefore predicted that normal bird census methods would not work for this species and instead we decided to use capture-recapture to estimate the population size (Bibby *et al.* 2000). This method has the advantage that the birds are marked individually and the individual capture histories are analysed. This means that individual birds being e.g. resident or straying will be taken into account differently in the calculation of a population estimate.

Mistnets were erected at 11 study sites. Four of these were located above Tegetero on the east slope of the Uluguru North Forest Reserve at altitudes of 1,400, 1,600, 1,800 and 2,000 m. Two sites were chosen on the west slope of the

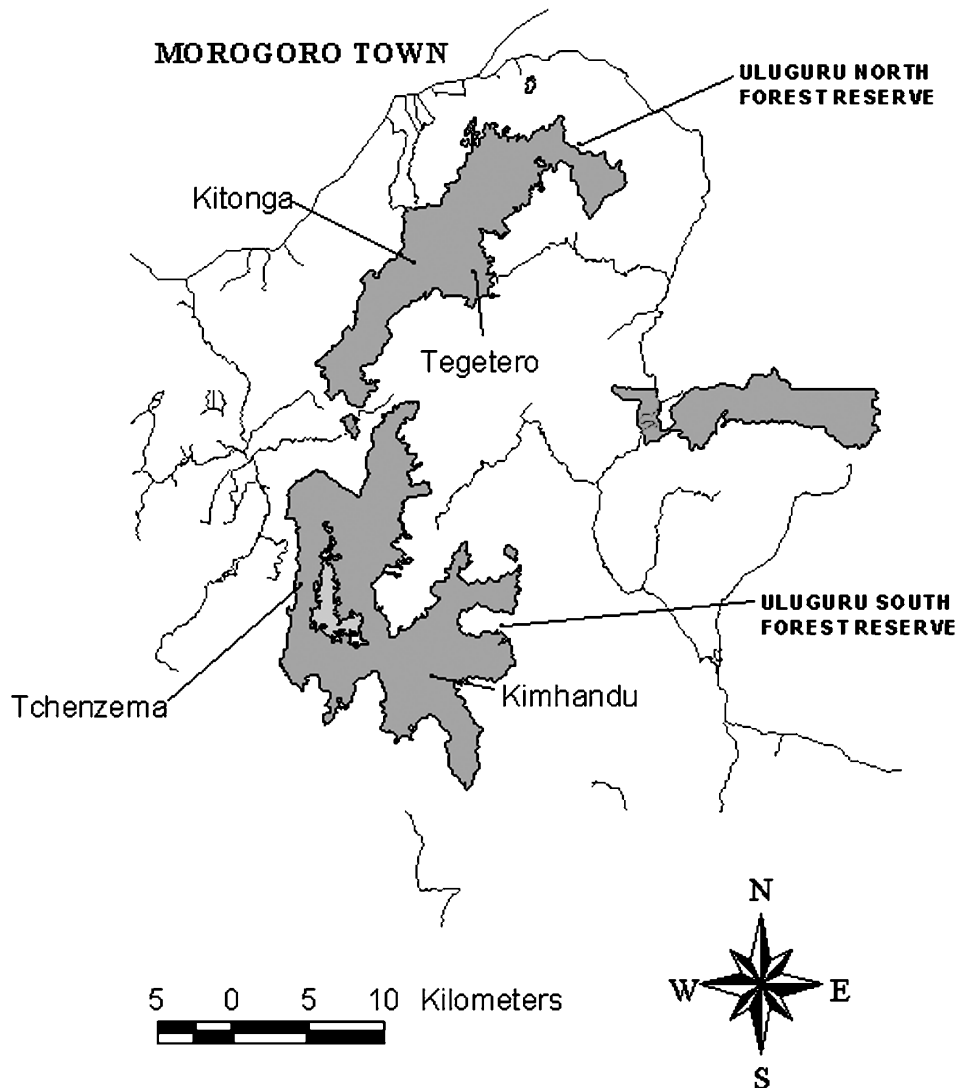


Figure 1. The Uluguru Mountains with the locations of the four main study areas.

Uluguru North Forest Reserve above Kitonga at altitudes of 1,600 and 1,800 m. In the Uluguru South Forest Reserve two sites were located at altitudes of 2,200 and 2,400 m, above Tchenzema on the west slope. Below Kimhandu Peak on the east slope three sites were located at altitudes of 2,000, 2,200 and 2,500 m.

Each site was visited for five days, and 15 mistnets (197 net-metres) were opened for ten hours each day. The nets were placed as randomly as possible in the area (with the constraint of difficult topography), and at right angles to each other to avoid shadow effects. The mistnets were preferably placed along contours and only rarely on the top of ridges, as these nets were subjected to more wind and therefore easier for the birds to detect.

Net rounds were carried out at one hour intervals. Captured Loveridge's Sunbirds were individually marked either by a combination of colour rings or by numbered metal rings. Furthermore, we recorded date, time, sex, weight and location of all captures and recaptures. Bird species other than Loveridge's Sunbird were recorded but released unmarked.

The population size of Loveridge's Sunbird at each study site (Table 1) was calculated using the program CAPTURE included in the program MARK (White and Burnham 1999), which produces an estimated population size for each study site. The program's model selection algorithm was used to select the most appropriate estimator for each dataset. We assumed that the population was closed, meaning that no emigration, immigration, deaths or births of significance occurred during the very short catching period at each site (five days). The field-work was conducted in the main breeding season, which minimizes the risk of bias caused by migrational movements.

Program Mark gives a population estimate for an area of unknown size. Therefore the effective catch area is needed to convert the population estimate into a density. We assume that the effective catch area is equal to the expected home range. The degree of overlap of home ranges is unknown, however as the densities are calculated from the population estimate given by MARK and the assumed effective catch area only the expected home ranges are needed to estimate a population density. Since the home range of Loveridge's Sunbird is unknown, potential population densities at the 11 study sites were calculated by assuming home ranges ranging from 0 km² through to 3 km². The population density of each study site was calculated by dividing the population size by the effective catch area. The density for each altitude was assumed equal for the entire altitudinal band. Where an altitude was visited twice, the average of the two densities was used. Once the population densities at different altitudinal bands were calculated, an overall population estimate of the species in the Uluguru Mountains was made using forest cover data for different altitude bands. The forest cover data we used were derived from aerial photographs from

Table 1. Estimates of the population (n) of Loveridge's Sunbird at each of the 11 study sites in the Uluguru Mountains, calculated by using Program CAPTURE (White and Burnham 1999)

Study site	Lower C.L.	Population estimate (n)	Upper C.L.	S.E.	Home range in km ²	Density in n/km^2
Kimhandu 2000	25	35	65	91.756	0.45	78
Kimhandu 2200	48	72	134	203.436	0.45	160
Kimhandu 2500	44	66	128	198.079	0.45	147
Kitonga 1600	46	36	74	8.944	0.45	80
Kitonga 1800	99	81	135	13.416	0.45	180
Tchenzema 2200	93	122	179	211.969	0.45	271
Tchenzema 2400	11	11	11	0.372	0.45	24
Tegetero 1400	36	46	75	95.454	0.45	102
Tegetero 1600	96	113	213	232.658	0.45	251
Tegetero 1800	89	75	126	122.474	0.45	167
Tegetero 2000	60	48	90	10	0.45	107

Upper and Lower Confidence Limits and Standard Error of these population estimates are indicated. In this table the home range for the species is set at 0.45 km².

1977 applied over a Digital Elevation Model of the Ulugurus and then sampled in 100 m bands across the mountain using ArcInfo GIS (Table 1) (see also Burgess *et al.* 2002).

Results

A total of 609 Loveridge's Sunbirds were captured, of which 138 were recaptures. They were only found in the Uluguru North, Uluguru South and Bunduki Forest Reserves. None were found in the smaller reserves on the Ulugurus that were investigated. The population sizes at the 11 different study sites ranged from 11 to 122 individuals (Table 1). The theoretical range in the total population size depending on different home ranges was calculated using the estimated population sizes from the 11 study sites. The relationship between the total population size (N) and home range (A) followed the equation $N = 16,637A^{-1}$ (Figure 2).

We used recaptures during the fieldwork to provide an estimate of the actual home range size of this species in order to refine our population assessment for this species. At two study sites separated by 1 km distance we recaptured only two individuals. This may be considered as the extreme travel distance of the species, with the maximum home range calculated as a circular area with a diameter of 1 km (0.8 km^2). Recaptures within our study sites were common up to a distance of 400 m. Thus, the lower extent of the home range is not likely to be less than a circular area with a diameter of 400 m, or 0.1 km^2 . If we fix the lower and upper home range sizes for this species at 0.1 km^2 and 0.8 km^2 , we obtain an estimated total population ranging from 21,000 to 166,000 individuals (Figure 2). However, if we take a median home range of 0.45 km^2 and use this to calculate the number of birds across the known area of forest in different

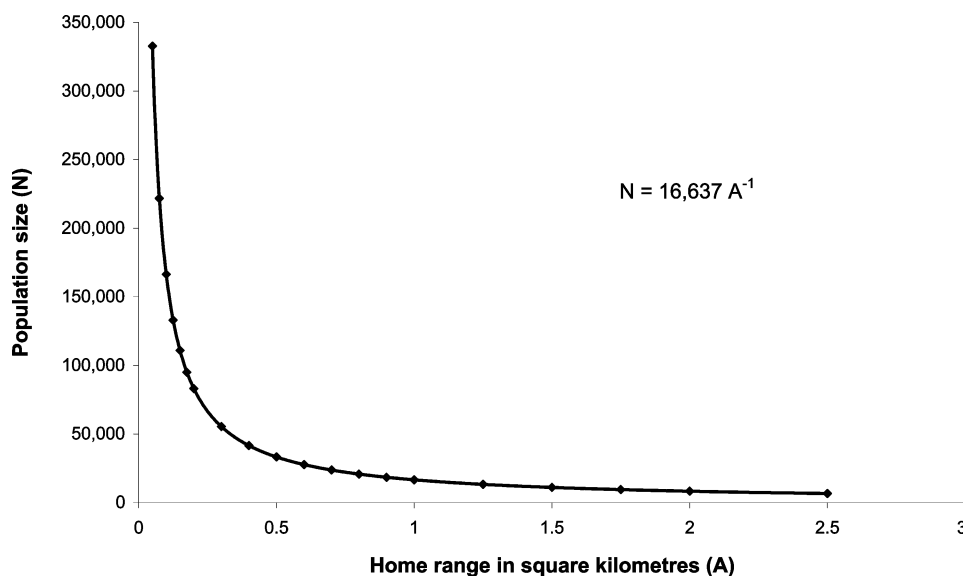


Figure 2. The population of Loveridge's Sunbird according to different home range sizes.

Table 2. Estimates of the population of Loveridge's Sunbird in different altitudinal bands of the Uluguru Mountains forests

Altitude band	Forest cover in km ²	Density in n/km ^{2a}	Population estimate
1,300 + 1,400 m	32,742	102	3,347
1,500 + 1,600 m	54,931	166	9,094
1,700 + 1,800 m	66,495	173	11,526
1,900 + 2,000 m	47,861	92	4,414
2,100 + 2,200 m	28,578	216	6,160
>2,300 m	28,405	86	2,430
Total	259,012		36,971

The forest cover data are derived from aerial photographs from 1977 applied over a Digital Elevation Model of the Ulugurus and then sampled in 100 m bands across the mountain (see Burgess *et al.* 2002). Population of Loveridge's Sunbirds in each altitudinal band was calculated with the home range size set at 0.45 km².

^a Where an altitude was visited twice, the average of the two density values was used in the final calculation of the population estimate.

altitudinal bands, the population of this bird is estimated as 36,971 individuals (Table 1 and 2).

Discussion

During our fieldwork we found the highest populations of this bird at 1,800 and 2,200 m, whereas Svendsen and Hansen (1995) had the highest catch rates at the same time of the year in the altitudes 1,520 and 1,920 m. Our two estimates of the population density around 2,000 m are also low compared to estimates for adjacent altitude bands. The explanation may be that these two study sites were less suited for mistnetting, which in turn could mean that fewer birds were caught. Hence, the study sites we used may bias our results for this altitude band. Given these kinds of variation in our field data, more than 11 field study sites might be needed to produce more robust population estimates, but at a considerable cost in terms of time in the field.

In the calculation of the total population, we used the 1977 forest area (260 km² surface area) for all forest at >1,300 m altitude. Since 1977, there has been some clearing of forest on the Ulugurus (see Burgess *et al.* 2002) and our calculations could be expected to overestimate the current population of the species. However, the forest below 1,300 m, where most of the recent forest clearing has occurred, has never been an important habitat for Loveridge's Sunbird, which is primarily a montane forest species (Cheke *et al.* 2001). We therefore believe that the use of these old forest cover data will have a negligible effect on our results, and hence that our population estimates for this species are not affected by this issue.

The home range may vary over altitude influenced by, for example, habitat structure and food availability. In this study we have assumed the same home range size in all altitudinal bands. It is possible that a more precise estimate of the total population could be obtained if the variation in home range size were addressed.

In conclusion, Loveridge's Sunbird has a large population within Uluguru North and South Forest Reserves, and Bunduki reserve, but is absent from other

smaller reserves on the Ulugurus. The forests of the Ulugurus are under threat from illegal cutting and conversion into farmland, but this mainly affects forest at altitudes, which are not preferred by this species of sunbird (Burgess *et al.* 2002, Svendsen and Hansen 1995). Hence we conclude that Loveridge's sunbird stands a good chance of surviving on the Ulugurus for many decades. By replicating this study it should be possible to detect any significant decline in the population of the species. Furthermore, future studies on home ranges of montane forest sunbirds will further assist in the interpretation of the results of this study, and future survey attempts may consider using line transect and mistnetting approaches in tandem to try and further refine population estimates for this species.

Acknowledgements

We thank the Wildlife Conservation Society of Tanzania (WCST-Birdlife Tanzania) and the Danish Ornithological Society (DOF-Birdlife Denmark) for the opportunity to conduct this project, and especially Anita Pedersen for helping with the preparations. For assistance in the field, we would like to thank Jacob Kiure for help and friendship during the long fieldwork periods. Special thanks go to Morten Frederiksen for help with the data processing and Carsten Egevang, Louis A. Hansen, Jon Fjeldså and Lene Hesselberg for comments on the manuscript.

References

- Bibby, C. J., Burgess, N. D., Hill, A. H. and Mustoe, S. H. (2000) *Bird census techniques*. London.: Academic Press.
- BirdLife International (2000) *Threatened birds of the world*. Cambridge U.K. and Barcelona: BirdLife and Lynx Editions.
- Brooks, T., Balmford, A., Burgess, N., Fjeldså, J., Hansen, L. A., Moore, J., Rahbek, C. and Williams, P. (2001) Toward a blueprint for conservation in Africa. *BioScience* 51: 613–624.
- Burgess, N. D., Fjeldså, J. and Botterweg, R. (1998) Faunal importance of the Eastern Arc mountains of Kenya and Tanzania. *J. East Afr. Nat. Hist.* 87: 37–58.
- Burgess, N. D., Romdal, T. S. and M. Rahner, M. (2001) Forest loss on the Ulugurus, Tanzania and the status of the Uluguru Bush Shrike *Malconotus alius*. *Bull. Afr. Bird Club* 8: 89–90.
- Burgess, N. D., Daggart, N. and Lovett, J. C. (2002) The Uluguru Mountains of eastern Tanzania: the effect of forest loss on biodiversity. *Oryx* 36: 140–152.
- Cheke, R. A., Mann, C. F. and Allen, R. (2001) *Sunbirds, a guide to the sunbirds, flowerpeckers, spiderhunters and sugarbirds of the world*. London: Helm, A & C Black.
- Collar, N. J. and Stuart, S. N. (1988) *Key forests for threatened birds in Africa*. Cambridge, U.K.: International Council for Bird Preservation. (ICBP monogr. 3.)
- Hartert, E. (1922) Exhibition and description of some new African birds. *Bull. Brit. Orn. Club* 42: 49–50.
- Lovett, J. C. (1988) Endemism and affinities of the Tanzanian montane forest flora. Pp. 591–598 in Goldblatt, P. and P.P. Lowry, eds. Proceedings of the eleventh plenary meeting in the Association for the Taxonomic Study of Tropical Africa. *Monographs in Systematic Botany from Missouri Botanical Gardens* 25.
- Lovett, J. C. and Pócs, T. (1993) Assessment of the Condition of the Catchment Forest Reserves, a botanical appraisal. Dar es Salaam, Tanzania: Prepared for The Catchment

- Forestry Project, under the Forestry and Beekeeping Division. Ministry of Tourism, Natural Resources and Environment.
- Lovett, J. C. and Wasser, S. K., eds. (1993) *Biogeography and ecology of the rainforests of eastern Africa*. Cambridge, U.K.: Cambridge University Press.
- Lovett, J. C., Fjeldså, J. and Svendsen, J. O. (1995) Section 3. Background information on the Uluguru forests. Pp. 25–29 in J. O. Svendsen and L. A. Hansen, eds. *Report on the Uluguru Biodiversity Survey 1993*. Sandy, U.K.: The Royal Society for the Protection of Birds, Danish Centre for Tropical Biodiversity and Tanzania Forestry Research Institute.
- Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.
- Pócs, T. (1976a) New or little known epiphyllous liverworts I. *Cololejeunea* from tropical Africa. *Acta Bot. Acad. Sci. Hung.* 22: 353–375.
- Pócs, T. (1976b) Vegetation mapping in the Uluguru Mountains (Tanzania, East Africa). *Boissera* 24: 477–498.
- Scharff, N., Stoltze, M. and Jensen, F. P. (1982) The Uluguru Mountains. Report of a study-tour 1981. Unpublished report from Zoological Museum of Copenhagen.
- Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998) *Endemic Bird Areas of the world. Priorities for biodiversity conservation*. Cambridge U.K.: BirdLife International.
- Stuart, S. N. and Jensen, F.P. (1985) The avifauna of the Uluguru Mountains, Tanzania. *Le Gerfaut* 75: 155–197.
- Stuart, S. N., Jensen, F. P., Brøgger-Jensen, S. and Miller, R. I. (1993) The zoogeography of the montane forest avifauna of eastern Tanzania. Pp. 203–228 in J. C. Lovett and S. K. Wasser, eds. *Biogeography and ecology of the rain forests of eastern Africa*. Cambridge, U.K.: Cambridge University Press.
- Svendsen, J. O. and Hansen, L. A., eds. (1995) *Report on the Uluguru Biodiversity Survey 1993*. Parts A and B. Tanzania Forestry Research Institute. Sandy, U.K.: Royal Society for the Protection of Birds, U.K. and Danish Centre for Tropical Biodiversity.
- White, G. C. and Burnham K. P. (1999) Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46 (Supplement): 120–138.

ANDERS P. TØTTRUP¹ and JØRN LENNART LARSEN
 Zoological Museum of Copenhagen, University of Copenhagen, Universitetsparken 15, 2100
 Copenhagen Ø, Denmark. E-mail at@it.dk

NEIL D. BURGESS²
 Uluguru Mountains Biodiversity Conservation Project, P.O. Box 312, Morogoro, Tanzania.

¹Author for correspondence.

²Current address: Conservation Science Programme, WWF-US, 1250 24th Street NW, Washington D.C., U.S.A.

Received 25 September 2002; revision accepted 27 August 2003