Bird Conservation International (2007) 17:141–150. © BirdLife International 2007
doi: 10.1017/S0959270907000664 Printed in the United Kingdom

Population status and distribution of Taita White-eye *Zosterops silvanus* in the fragmented forests of Taita Hills and Mount Kasigau, Kenya

RONALD K. MULWA, LEON A. BENNUN, CALLISTUS K. P. O. OGOL and LUC LENS

Summary

Our study focused on the Taita White-eye *Zosterops silvanus*, one of three bird species endemic to the Taita Hill forests, south-east Kenya. Formerly considered Critically Endangered, Taita White-eye has been down-listed to Endangered following the findings of this study. Between November 1998 and September 1999 we counted this species along line transects to establish their current population status and distribution in its entire range. White-eye censuses were conducted in nine forest fragments of the Taita Hills and the virtually undisturbed Mt Kasigau forest. The total global population of Taita White-eyes was estimated to be *c.* 7,100 birds. Mt Kasigau was shown to be the species' main stronghold, maintaining a very high density (26 birds ha^{-1}) and holding 80% (5,600 individuals) of the entire population. In the Taita Hills forests, densities were consistently higher in the small isolated fragments than in the large ones, though the former held only a small population (3% of total). At Mt Sagala, a large isolated block where indigenous trees have been largely replaced with exotic plantation, this species was not encountered. We found no evidence of interchange between the White-eye populations on Mt Kasigau and the Taita Hills forests, probably because of the separation by a low-altitude, dry woodland habitat barrier. While prioritization for conservation action should focus more on the Taita Hills forest fragments, Mt Kasigau should be treated as fragile ecosystem which holds a huge, apparently insular population of Taita White-eyes.

Introduction

Taita Hills and Mt Kasigau are tropical montane cloud-forests forming the northernmost outlier of the Eastern Arc Mountains of Tanzania and south-east Kenya (Lovett 1988, Lovett and Wasser 1993, CI and ICIPE 2003). The Eastern Arc Mountains (together with coastal forests) of Kenya and Tanzania are one of the smallest of the 25 global biodiversity hotspots (Mittermeier *et al.* 1998, Myers *et al.* 2000, Burgess *et al.* 2003, CI and ICIPE 2003), containing 160 Key Biodiversity Areas (KBAs) (Burgess *et al.* 2003). Taita Hills forests are recognized as one of Kenya's 60 Important Bird Areas (IBAs) while Mt Kasigau is designated as a Potential IBA (Bennun and Njoroge 1999).

Apart from the Taita White-eye, two other bird species, both Critically Endangered, are endemic to the Taita Hills forests: the Taita Thrush *Turdus helleri* and Taita Apalis *Apalis fuscigularis* (Fanshawe and Bennun 1991, Collar *et al.* 1994, Zimmerman *et al.* 1996, BirdLife International 2000, Bennun and Njoroge 2001). Other Taita endemics include reptile and amphibian species (Beentje *et al.* 1987), three butterfly species (Larsen 1991) and several plant species (Beentje 1988).

The Taita White-eye has a very small range, within which it is restricted to a very small area of forest that is severely fragmented and declining in extent and quality (Collar *et al.* 1994, Brooks *et al.* 1998). It certainly remains at risk due to the increasing human population pressure leading to habitat degradation through removal of trees from the core of its small range (Brooks *et al.* 1998, Lens *et al.* 1999, BirdLife International 2000). In view of the current threats facing the Taita Hills ecosystem, and lack of prior information on the population status of the Taita White-eye, we embarked on this study to collect baseline data which would be useful in informing conservation action to ensure the survival of the species.

The overall aim of this study was to assess the population status and distribution of Taita White-eye within the entire Taita Hills ecosystem. We sought to answer the following specific questions: (i) In what densities do Taita White-eyes occur in the various forest fragments? (ii) What are the sizes of the White-eye subpopulations occurring in the various forest remnants? (iii) To what extent are inter-fragment dispersal movements possible?

Methods

Study area

The Taita Hills lie in the south-east of Kenya (03°25′ S, 38°20′ E) about 150 km inland from the coast and cover an area of about 250 km^2 (Brooks *et al.* 1998). The hills occur as three main blocks: the Dawida (highest peak 2,230 m), Mbololo (2,200 m) and Sagala (1,450 m) massifs (Brooks *et al.* 1998; see Figure 1). Some 50 km to the south-east lies Mt Kasigau forest (1,680 m), which has biogeographical affinities, though weak, with the Taita Hills forests (Collar and Stuart 1988).

Mt Kasigau is largely undisturbed and has a pristine moist forest at the higher altitudes (>1,300 m), grading into dry woodland and scrub on the lower slopes (500 m) (Barnes *et al.* 1999). Taita Hills forests are today reduced to tiny fragments on the hilltops and ridges ranging in size from 200 ha to less than 1 ha and covering only 600 ha in total (Brooks *et al.* 1998). Some of the fragments have been reduced further by the introduction of invasive exotic plantations, particularly *Pinus patula* (Mulwa 2001).

Human pressure on these minuscule forest patches remains extremely high, and many are already severely degraded (Brooks *et al.* 1998, Lens *et al.* 1999, Burgess *et al.* 2001). This site has therefore been categorized as one of the 19 Critically Threatened IBA sites where intense and immediate conservation action is needed (Bennun and Njoroge 1999). Despite the remaining forests being small, they are important as water catchments for the local communities and refugia for unique biodiversity.

Study design

White-eye censuses were conducted between 07h30 and 11h30 and again from 15h30 to 17h30 when birds were most active. Birds were counted along line transects according to the Distance Sampling Protocol described by Buckland *et al.* (1993). Some important features of Distance Sampling are: (i) perpendicular distance should be measured from transect line to the animal's original location, (ii) movement of animals after detection is not a problem as long as the original location can be established accurately and the appropriate distance measured, (iii) it is of no concern if an animal is detected more than once along the same transect and (iv) the programme fully allows for the fact that many animals not on the transect line will remain undetected (Buckland *et al.* 1993).

A total of 119 transects, covering 56.3 km and ranging from 200 m to 1 km in length, were laid out in different fragments. The number and length of transects were determined by the

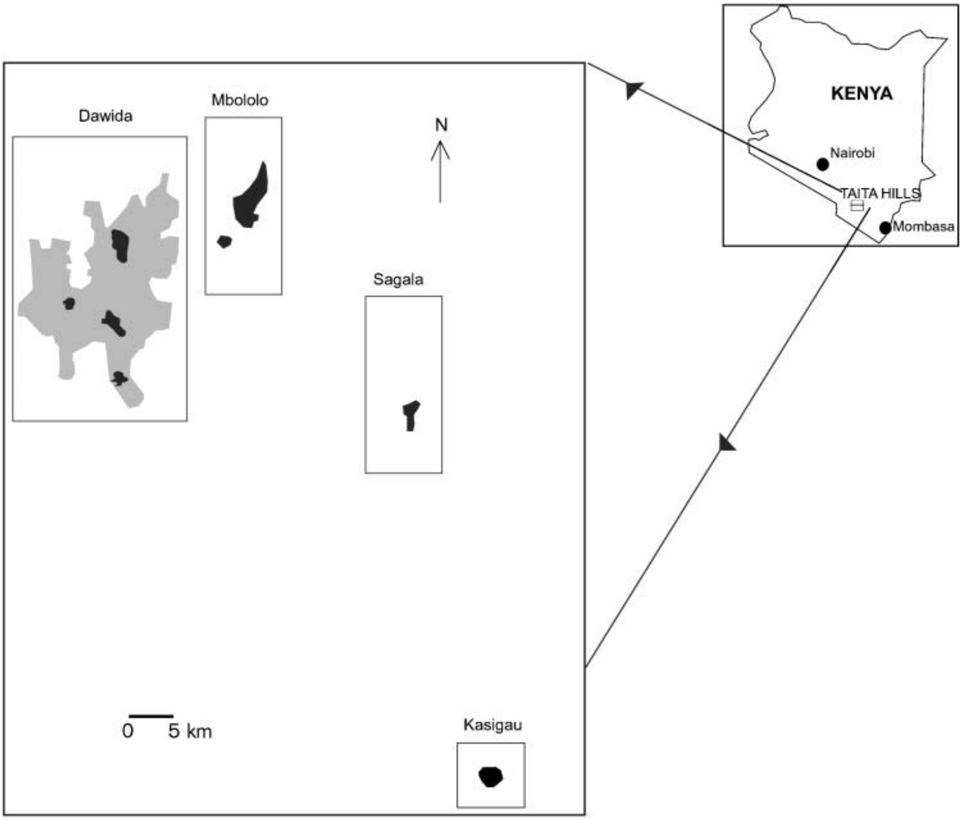

Figure 1. The location of the Taita Hills forest fragments and their spatial distribution.

fragment size and made use of existing trails as far as possible rather than cutting vegetation. Transects in the forest interior were used to assess population densities while two 1 km, randomly laid transects into the farmlands assessed the birds' use of the agricultural matrix. Inter-fragment movement by Taita white-eyes was assessed by observing some 438 birds, colour-ringed between 1996 and 1999 in Mbololo and Dawida as part of another study (Lens *et al.* 2002). At Mt Kasigau, low-altitude transects were placed along the four main compass directions. These were used as 'controls' because the birds are unlikely to occur in the lower altitude dry woodland habitat.

We walked transects slowly (at a speed of 1.5 km/h), making frequent stops to look for and listen to the birds. Once a flock was seen or heard, the observers marked original locations, then left the transect briefly, so as to count the birds under the thick canopy before they moved from their original locations. With the aid of 10 × 50 binoculars, we counted the individual birds in each flock. Where dense canopy or heavy mist hindered visibility, counting was achieved as the birds moved from one tree to another, especially if they flew across open gaps between the trees.

To minimize time-of-day bias, each transect was accorded an equal chance of being run at different times of day. This was achieved by dividing the census session (i.e. 07h30–11h30 and 15h30–17h30) into four blocks: early morning (07h30–09h30), late morning (09h30–11h30), early afternoon (15h30–16h30) and late afternoon (16h30–17h30). The following information was gathered: (i) flock size of birds sighted, (ii) perpendicular distance of the flock location from transect line and (iii) transect length (which was multiplied by number of transect runs in analysis).

In all fragments where White-eyes occurred, a constant effort of six runs per transect was applied during wet and dry seasons, though not equally distributed in all sites due to logistical practicalities. The very wet seasons were avoided.

DISTANCE version 3.5 (Buckland *et al.* 1993) was used to analyse the data. Only transects located within the forest interior were used for density computation. Data collection lasted 11 months, from November 1998 to September 1999.

Results

Occurrence across fragments and matrices

Taita White-eyes were encountered in a total of 10 sites: all the eight main fragments of the Dawida block, Mbololo and Mt Kasigau forests (Table 1). Efforts to locate the species in the isolated and *Pinus-patula*-dominated Mt Sagala fragment were unsuccessful.

White-eyes were encountered foraging in bushy hedgerows and isolated or clustered trees in high-altitude farmlands in the Dawida block and around Mbololo. Birds encountered in farmland around the three main fragments included: 28 birds in nine sightings from Ngangao, 24 birds in four sightings from Chawia, and 22 birds in seven sightings from Mbololo. Some of the birds were moving towards the forest fragments and others into the surrounding farmland matrices. In the isolated Mt Kasigau forest, the White-eyes were only encountered in the wetter, high-altitude habitat between 850 m and the peak, 1680 m.

Flock sizes

Mt Kasigau had significantly larger White-eye flocks (mean 16.9 ± 2.7 birds) than all other forests (mean 4 ± 5.3 birds) ($t = 8.3$, df = 37; $P < 0.0001$). The largest flock of 135 birds was encountered at Mt Kasigau; flocks of over 80 birds were not uncommon at this site, in contrast to other sites where White-eye flocks rarely exceeded 15 birds (Table 2). An ANOVA test between flock sizes in Dawida and Mbololo massifs showed significant differences ($F_{8,298} = 3.04$, $P = 0.003$), flocks in Mbololo and Vuria being significantly smaller than those at Ngangao (Tukey test, Table 2). With the exception of Mt Kasigau, flock encounter rate at a site had a negative correlation with fragment size ($r = -0.74$, 95% CI). The modal flock size was two birds in all but one fragment, Vuria, where birds occurring singly were the commonest. Our data allowed

Table 1. Taita White-eye densities (birds ha^{-1}) in Taita Hills and Mt Kasigau forests, together with DISTANCE model selection statistics using the Akaike Information Criterion and χ^2 goodness of fit.

Fragment size (ha)	Minimum density	Density estimate ± SE	Maximum density	Selected model/Adjustment term	Effective Strip Width (ESW)	Minimum AIC	χ^2 P value
Ndiwenyi (1.7)	7.4	15.5 ± 5.7	32.4	Half-normal/Cosine	8	52.7	0.4
Mwachora (2)	4.2	15.5 ± 8.4	57.2	Uniform/None	6	14.3	1.0
Macha (3)	2.3	9.7 ± 7.5	41.0	Hazard rate/None	30	90.2	0.7
Fururu (4.5)	3.5	7.0 ± 2.5	14.2	Uniform/Cosine	25	89.5	0.3
Yale (5)	1.4	4.6 ± 2.3	14.8	Uniform/Cosine	40	42.0	0.7
Vuria 10.5)	1.6	3.7 ± 1.5	8.3	Hazard rate/None	50	174	0.2
Chawia (50)	2.7	4.4 ± 1.0	7.4	Uniform/Cosine	50	210	0.1
Ngangao (92)	2.8	5.2 ± 1.6	9.7	Uniform/Cosine	40	180	0.2
Mbololo (220)	1.6	3.5 ± 0.9	5.4	Negative exponential/None	30	225	0.2
Kasigau (216)	13.69	25.9 ± 8.6	49.2	Hazard Rate/None	40	473	0.2

Note: Minimum and maximum density values are at the 95% confidence interval.

https://doi.org/10.1017/S0959270907000664 Published online by Cambridge University Press

Table 2. Summary of Taita White-eye flocking behaviour in different-sized fragments.

Fragment	Mean flock size ± SE	*N*	Flock/ha	Encounter rate (flocks km^{-1})	Largest flock observed
Ndiwenyi	4.3 ± 1.2^a	11	3.6 ± 0.9	7.2	14
Mwachora	3.0 ± 0.9^a	14	5.6 ± 2.6	6.7	5
Macha	3.0 ± 0.9^a	14	4.0 ± 2.9	6.7	12
Fururu	3.3 ± 0.4^a	15	1.8 ± 0.6	5.9	7
Yale	4.4 ± 0.9^a	25	1.9 ± 0.7	5.8	20
Vuria	2.7 ± 0.6^b	27	1.4 ± 0.5	3.1	15
Chawia	5.3 ± 1.1^a	58	0.7 ± 0.8	2.6	50
Ngangao	6.6 ± 0.9^c	51	0.7 ± 0.2	2.6	30
Mbololo	2.8 ± 0.3^b	92	1.0 ± 0.3	1.9	25
Kasigau	16.9 ± 2.7^d	84	1.6 ± 0.4	4.6	135

Results of a Tukey post-hoc test on flock size are indicated by letters where significant (significantly different mean values are assigned different letters).

for seasonal flocking comparisons in only three sites; Mbololo, Ngangao and Chawia. Only in Chawia forest were flocks sizes significantly higher in the drier season ($t = 2.7$, df = 56, $P < 0.008$).

Population density, size and distribution

Population densities varied among study sites (Table 1). Mt Kasigau had the highest White-eye density (26 birds ha^{-1}) and Mbololo the lowest (3 birds ha^{-1}). Ngangao and Chawia, the two main fragments of the Dawida massif, had nearly similar densities (5.2 and 4.4 birds ha^{-1}, respectively), while the smaller fragments had the highest density (up to 15 birds ha^{-1}) in Dawida. There was a negative correlation between White-eye density and fragment size in these small Dawida block fragments below 10 ha ($r = -0.98$, 95% CI). Excluding Mt Kasigau and Mbololo forests, there was a positive correlation between population size and fragment size ($r = 0.74$) for all other fragments.

The total Taita White-eye population living in various fragments of the Taita Hills ecosystem was estimated at 7,120. Mt Kasigau was shown to be the main stronghold of the Taita White-eye, having the vast majority of the birds (78%, 5,594 individuals; Table 3). Though densities were high in the smallest Dawida fragments, they held only a small population (3% of the total).

Table 3. Taita White-eye population size in various forest fragments of the Taita Hills and Mt Kasigau (results of DISTANCE analysis).

Fragment	Minimum	Estimated population	Maximum	% of estimated population
Ndiwenyi	13	26	55	
Mwachora	8	31	114	
Macha	7	29	123	3
Fururu	16	32	64	
Yale	7	23	74	
Vuria	16.8	39	87	
Chawia	135	220	370	3
Ngangao	258	478	892	7
Mbololo	352	651	1188	9
Kasigau	2957	5594	10627	78
Totals	3769	7123	13594	

Note: Minimum and maximum values are based on the 95% confidence interval.

https://doi.org/10.1017/S0959270907000664 Published online by Cambridge University Press

Discussion

Though there is no documented historical evidence of the existence of Taita White-eyes in Mt Sagala, it is possible that they once occurred here and underwent local extinction following the replacement of indigenous forest with *Pinus patula*, which according to Mulwa (2001) is unsuitable habitat for the birds. White-eye occurrence in farmlands between forest fragments, especially within the Dawida and Mbololo massifs, implies that they are capable of moving between these fragments. This was confirmed by capture–recapture studies, where Taita White-eyes were shown to have the highest dispersal probability between any two fragment pairs among Ngangao, Chawia and Mbololo compared with other Taita endemics (Lens *et al.* 2002). Considering that Taita White-eyes are typically high-altitude, moist-forest species, as supported by their non-occurrence in the lower altitude dry lands, the 50 km stretch of dry lowland woodland between Mt Kasigau and the Taita Hills forests may be acting as an effective habitat barrier between these populations. Therefore, the population on this mountain may be insular, which makes the birds highly vulnerable to negative inbreeding consequences or local extinction in case of any stochastic event.

The occurrence of larger White-eye flocks at Mt Kasigau than in other forests is attributable to the high abundance of the White-eyes' preferred food resources here due to low disturbance (Mulwa 2001). This is consistent with Perins and Birkhead's (1983) view that high quantities of food are often associated with large concentrations of birds. Kosgey (1998), working on the Turner's Eremomela *Eremomela turneri* in south Nandi Forest, Kenya, found similar patterns. As a result of forest disturbance, the White-eyes' habitat quality in the Taita Hills forests may have deteriorated. This may explain the observed small flock sizes in the smaller fragments, possibly in order to reduce intra-specific competition. However, Mbololo forest is the largest and possibly most undisturbed forest among the Taita Hills, yet it had small Taita White-eye flock sizes. A possible explanation for this observation is that during this study there was much breeding activity in Mbololo (Mulwa 2001). It is therefore arguable that most of the flocks encountered here were in small breeding pairs, as has been shown by Campbell and Lack (1985) for white-eyes.

High Taita White-eye population density in Mt Kasigau forest compared with other forests is also largely due to availability of food resources and low habitat disturbance at this site (Mulwa 2001). According to Gaston (1978) and O'Connor and Fuller (1986) survival and reproductive success in such high-quality habitats are expected to be high. The high population density is also attributable to the 'fence effect' resulting from the restricted dispersal of these birds, as is known to be the case for animals living on island habitats (Krebs *et al.* 1969). Such high population density in fairly small areas is common among white-eyes. Elsewhere, other white-eye species are known to establish themselves in remote islands better than any other family of passerines and often reach very high densities (Skead 1967). For example, in the Great Barrier Reef, Australia, Campbell and Lack (1985) recorded 200 pairs breeding in 16 ha of Heron Island. Other examples include: the near-extinct *Z. albogularis* endemic to Norfolk Island, *Z. strenua* endemic to Lord Howe Island, *Z. modesta* of the Seychelles (Campbell and Lack 1985) and *Z. borbonica* of Mauritius and the Reunion Islands (Gill 1971).

The negative correlation between Taita White-eye densities and fragment size among the smaller fragments can be explained in terms of existing information (e.g. Campbell and Lack 1985, Zimmerman *et al.* 1996) and our own observations that Taita White-eyes are generalist edge species. It is possible that birds wandering in the agricultural matrix may perceive any forest patch (no matter how small) as a better habitat than the surrounding farmlands. Therefore they may end up converging in such small fragments in high densities. Holt (1987) has referred to such small forest patches as 'habitat dumps' where 'refugees' from lost habitats and surrounding matrix collect in unusually high densities. Also, in the larger Taita Hills forest fragments, the only sites where breeding activity was recorded (Mulwa 2001), the birds occurred in relatively lower densities than in the small fragments. Svärdson (1949), Brown (1969) and

https://doi.org/10.1017/S0959270907000664 Published online by Cambridge University Press

Fretwell and Lucas (1969) have argued that breeding individuals may force subordinate individuals into low-quality 'sink' habitats where densities may build up to high levels (Lidiker 1975, Wiens and Rotenberry 1981).

Numerical modelling has repeatedly indicated that inter-patch dispersal is important in preventing global extinction of species metapopulations in fragmented systems (e.g. Goodman 1987, Pulliam 1988), and a decrease in immigration rate due to isolation is one of the major predictions of island biogeography theory (MacArthur and Wilson 1967). If absence of Taita White-eyes in Mt Sagala today is a result of local extinction, this may mean that a rescue effect from the Taita Hills or Mt Kasigau could not have been achieved, due to the low-altitude dry habitat barrier between these sites. Similarly, Mt Kasigau's huge (possibly) insular Taita White-eye population is therefore highly vulnerable. On the other hand Taita White-eye subpopulations in the Dawida and Mbololo fragments, which are connected by dispersal (metapopulation), have a higher probability of persisting than a single population (Levins 1969, 1970, Temple 1991). This is because subpopulations are subject to stochastic extirpations (Goodman 1987), and large numbers of subpopulations provide an important hedge against simultaneous collapse of all subpopulations and, hence, the extirpation of the entire metapopulation (Temple 1991, Pulliam 1988).

In the absence of constant seasonal data collection effort from all sites, the rotational field visits made to the same sites in different seasons over the 11 month period are assumed to have adequately corrected for any seasonal effects. Generally there are no clear-cut wet and dry seasons in the Taita Hills, especially in the ever-misty hilltops. Furthermore, breeding records during this study indicate that the birds were breeding throughout the year (Mulwa 2001), when the birds largely occur in breeding pairs (Campbell and Lack 1985). This is further supported by the observed modal flock size of two birds and the lack of significant difference in seasonal flock sizes at two major fragments (Ngangao and Mbololo). However, in Chawia, flocks were larger in the dry than in the wet season, which is similar to observations by Borghesio and Laiolo (2004) among Kulal White-eyes *Zosterops kulalensis* in a single site in northern Kenya. The inconsistency in seasonal flocking among Taita White-eyes in different fragments may suggest lack of a profound effect on the flocking or densities in this metapopulation.

We speculate that the small fragments are very important stepping stones for the birds' dispersal within the Dawida and Mbololo massifs that enhance connectivity and reduced competition. This idea is supported by the increased White-eye flock encounter rate with diminishing fragment size in Dawida and Mbololo. In terms of conservation, this presents an opportunity for matrix management to help augment habitats around small forest patches to enhance gene flow for the more mobile and tolerant species such as the White-eyes.

Our results suggest that Mt Kasigau forest is of very high conservation value as the world's stronghold for the Taita White-eye population. The Kasigau forest is also rich in other unique forms of biodiversity, such as *Gulella spinosa*, a snail species new to Kenya (Lange *et al.* 1998). Because Mt Kasigau is now recognized as a Key Biodiversity Area (KBA) within the Taita Hills biogeographical complex, we believe this will help foster adequate conservation attention, effort and protection. Because of the potential importance of the small Taita Hills forest fragments as vital dispersal areas for White-eyes and other birds moving between the main fragments, they should be conserved and protected more strictly. Tolerance to edge-effects by the study species implies that the establishment of corridor habitats in the riparian matrix will enhance connectivity between fragments. This may take practical approaches such as promoting the maintenance of hedgerows, gallery forest patches in stream and valleys, kopjes, bushes, and even individual trees, which are also valuable for human use. These will act not only as refugia for biodiversity but also stepping stones for movement between the main Taita Hills fragments. Although human activities that increase habitat edge-effects (e.g. firewood collection, building poles and creation of footpaths) should be discouraged, projects and agencies working with local communities should promote livelihood activities that support the conservation of the habitat patches among human settlements.

Our research highlights the need for genetic studies to assess the relationship between the Taita White-eye populations in Mt Kasigau and the Taita Hills, and underscores the need for a monitoring scheme for Taita White-eyes and their habitat structure. Decreasing flock size has been linked to population declines in other white-eye species such as the Brindled White-eye *Zosterops conspicillata* (Craig 1994). Therefore, the effectiveness of the recommended conservation action given here for the Taita White-eye may be tested by a simple population-monitoring scheme in the Taita Hills and Mt Kasigau forests. This will involve training teams of community-based site conservation groups to conduct surveys to assess the flock sizes in relation to the results of the current study. This will be a good vehicle for creating conservation awareness among the local community while gauging the trends in Taita White-eye population and habitat quality, as has successfully happened elsewhere in Kenya.

Acknowledgements

This project would not have been possible without the generous financial support of Taita Hills Biodiversity Project (THBP), Royal Society for the Protection of Birds (RSPB), The Generoso Pope Foundation through the Wildlife Conservation Society's small grant programme, and The African Bird Club (ABC). We are very grateful to the Department of Ornithology, National Museums of Kenya for offering logistical support during the fieldwork.

References

Barnes, J., Barnes, R., Buston, P., Githiru, M., Leckie, J., Mulwa, R. and Pilgrim, J. (1999) Project Kasigau '98. Preliminary report.

Beentje, H. J. (1988) An ecological and floristic study of the Taita Hills, Kenya. *Utafiti* 1: 23–26.

Beentje, H. J., Ndiang'ui, N. and Mutangah, J. (1987) Forest islands in the mist. *Swara* 10: 20–21.

Bennun, L. A. and Njoroge, P. (1999) *Important bird areas of Kenya*. Nairobi: East Africa Natural History Society.

Bennun, L. A. and Njoroge, P. (2001) Kenya. Pp. 411–464 in L. D. C. Fishpool and M. I. Evans, eds. (2001) *Important bird Areas in Africa and associated Islands: Priority Sites for Conservation*. Newbury and Cambridge, U.K.: Pisces Publications and BirdLife International (BirdLife Conservation Series No. 11).

BirdLife International (2000) *Threatened birds of the world*. Barcelona and Cambridge, U.K.: Lynx Edicions and BirdLife International.

Borghesio, L. and Laiolo, P. (2004) Habitat use and feeding ecology of Kulal White-eye *Zosterops kulalensis*. *Bird Conserv. Int.* 14: 11–24.

Brooks, T., Lens, L., Barnes, J., Barnes, R., Kageche, J. K. and Wilder, C. (1998) The conservation status of the forest birds of the Taita Hills, Kenya. *Bird Conserv. Int.* 8: 119–139.

Brown, J. L. (1969) Territorial behaviour and population regulation in birds: a review and re-evaluation. *Wilson Bull.* 81: 293–329.

Buckland, S. T., Anderson, D. R., Burnhan, K. P. and Laake, J. L. (1993) *DISTANCE sampling: estimating abundance of biological populations*, 1st edn. London: Chapman and Hall.

Burgess, N. D., Lovett, J. C. and Muhanga, S. (2001) Biodiversity conservation and sustainable forest management in the eastern Arc Mountains. Unpublished Report prepared for GEF/PDFB Eastern Arc Strategy Process.

Burgess, N. D., Butynski, T., Gordon, I., Luke, Q., Sumbi, P. and Watkin, J. (2003) Eastern Arc Mountains and coastal forests of Tanzania and Kenya: Biodiversity hotspots. Ecosystem profile report prepared for Critical Ecosystem Partnership Fund.

Campbell, B. and Lack, E. (1985) *A dictionary of birds*. London: The British Ornithologists' Union and Pitman Press.

CI and ICIPE (2003) *Eastern Arc and coastal forests of Tanzania and Kenya biodiversity hotspots: an ecosystem profile*. Washington, DC: Conservation International and International Centre for Insect Physiology.

Collar, N. J. and Stuart, S. N. (1988) *Key forests for threatened birds in Africa*. Cambridge, U.K.: International Council for Bird Preservation.

Collar, N. J., Crosby, M. J. and Stattersfield, A. J. (1994) *Birds to watch 2. The world list of threatened birds*. Cambridge, U.K.: BirdLife International.

Craig, R. J. (1994) Notes on the ecology and population decline of the Rota Brindled White-eye *Zosterops conspicillata*. *Wilson Bull.* 106: 169–173.

Fanshawe, J. and Bennun, L. A. (1991) Bird conservation in Kenya: creating a national strategy. *Bird Conserv. Int.* 1: 293–315.

Fretwell, S. D. and Lucas, H. L. (1969) On terrestrial behaviour and other factors influencing habitat distribution in birds. I. Theoretical development. *Acta Biotheoretica* 9: 16–36.

Gaston, J. D. (1978) The ecology of the Common Babbler, *Turdoides caudatus*. *Ibis* 120: 415–432.

Gill, F. B. (1971) Ecology and evolution of the sympatric Mascarene White-eyes, *Zosterops borbonica* and *Z. olivacea*. *The Auk* 88: 35–60.

Goodman, D. (1987) Consideration of stochastic demography in the design and management of biological reserves. *Nat. Resources Modelling* 1: 205–234.

Holt, R. D. (1987) On the relation between niche overlap and competition: the effect of incommensurable niche dimensions. *Oikos* 48: 110–114.

Kosgey, D. K. (1998) Status and habitat choice of Turner's Eremomela, *Eremomela turneri*, in south Nandi forest reserve, Kenya. Unpublished MPhil. thesis, Moi University, Kenya.

Krebs, C. J., Keller, B. J. and Tamarin, B. H. (1969) *Microtus* population biology: demographic changes in fluctuating populations of *M. ochrogaster* and *M. pennysilvanicus* in southern Indiana. *Ecology* 50: 587–607.

Lange, C., Seddon, M. and Tattersfield, P. (1998) *Gulella spinosa*; new to Kenya. *J. Conchol.* 38: 48–49.

Larsen, T. B. (1991) *The butterflies of Kenya and their natural history*. Oxford: Oxford University Press.

Lens, L., Adriaensen, F. and Matthysen, E. (1999) Dispersal studies in recently and historically fragmented forests: a comparison between Kenya and Belgium. Pp. 2480–2491 in A. Adams and R. Slotow, eds. Proceedings of the 22nd International Ornithological Congress. Johannesburg: BirdLife South Africa.

Lens, L., Von Dongen, S., Norris, K., Githiru, M. and Matthysen, E. (2002) Avian persistence in fragmented rainforest. *Science* 298: 1236–1238.

Levins, R. (1969) The effect of random variations on different types on population growth. *Proc. Natl. Acad. Sci. U.S.A.* 62: 1061–1065.

Levins, R. (1970) Extinction. Pp. 77–107 in M. Gestenhaber, ed. *Some mathematical problems in biology*. Providence, Rhode Island: American Mathematics Society.

Lidiker, W. Z. Jr (1975) The role of dispersal in the demography of small mammals. Pp. 103–128 in F. B. Golley, K. Petrsewicz and L. Ryszkowski, eds. *Small mammals: their productivity and population dynamics*. Cambridge, U.K.: Cambridge University Press.

Lovett, J. C. (1988) Endemism and affinities of the Tanzanian montane forest flora. Pp. 591–598 in P. Goldblatt and P. P. Lowry, eds. *Modern systematic studies in African botany*. St Louis: Missouri Botanical Garden.

Lovett, J. C. and Wasser, S. K. (1993) *Biogeography and ecology of the rainforests of eastern Africa*. Cambridge, U.K.: Cambridge University Press.

MacArthur, R. H. and Wilson, E. O. (1967) *The theory of island biogeography*. Princeton, New Jersey: Princeton University Press.

Mittermeier, R. A., Myers, N. and Thomsen, J. B. (1998) Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conserv. Biol.* 12: 516–520.

Mulwa, R. K. (2001) The population status and ecology of Taita White-eye *Zosterops (Poliogaster) silvanus* (Peters and Loveridge 1935) in the fragmented forests of Taita hills, Kenya. M.Sc. thesis, Kenyatta University, Kenya.

Myers, N., Mittermeier, R. A., de Fonseca, G. A. B. and Kent, J. (2000) Biodiversity hotspots for conservation priority. *Nature* 403: 853–858.

O'Connor, R. J. and Fuller, R. J. (1986) Bird population responses to habitat. Pp. 197–211 in K. Taylor, R. J. Fuller and P. C. Lack, eds. *Bird census and atlas studies*. Tring, U.K.: British Trust for Ornithology.

Perins, C. M. and Birkhead, T. R. (1983) *Avian ecology*. Glasgow and London: Blackie and Sons.

Pulliam, H. R. (1988) Sources, sinks and population regulation. *Am. Nat.* 132: 652–661.

Skead, C. J. (1967) *Sunbirds of Southern Africa, also sugarbirds, white-eyes and spotted creeper*. Cape Town: A. A. Balkema.

Svärdson, G. (1949) Competition and habitat selection in birds. *Oikos* 1: 157–174.

Temple, S. A. (1991) The role of dispersal in the maintenance of bird populations in a fragmented landscape. *Acta XX Congressus Internationalis Ornithologici* 2298–2305.

Wiens, J. A. and Rotenberry, J. T. (1981) Censusing and evaluation of avian habitat occupancy. *Studies Avian Biol.* 6: 522–532.

Zimmerman, D. A., Turner, D. A. and Pearson, D. J. (1996) *Birds of Kenya and Northern Tanzania*. London: Christopher Helm.

RONALD K. MULWA*
Department of Ornithology, National Museums of Kenya, P. O. Box 40658, Nairobi, Kenya.

LEON A. BENNUN
BirdLife International, Wellbrook Court, Girton Road, Cambridge CB3 ONA, U.K.

CALLISTUS K. P. O. OGOL
Zoology Department, Kenyatta University, P. O. Box 43844, Nairobi, Kenya.

LUC LENS
Department of Biology, Terrestrial Ecology Unit, Ghent University, Ledeganckstraat 35 9000 Ghent, Belgium.

**Author for correspondence; e-mail: ronmulwa@yahoo.com*

Received 3 February 2005; revision accepted 22 May 2006