

Estimating the abundance of forest antelopes by using line transect techniques: a case from the Udzungwa Mountains of Tanzania

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We used line transect counts to collect data on population abundance of forest antelopes from three different moist forest sites within the Udzungwa Mountains, Tanzania. Habitat quality of these forests differs in forest size, vegetation type, human impact and level of protection. The red duiker (*Cephalophus harveyi* Thomas 1893) was the only species regularly seen (mean of 0.16 animals seen per km walked) from one of the three sites, Mwanihana Forest, which is a large forest block within the Udzungwa Mountains National Park ranging in altitude from 300-2100 m. Counts of antelope track and dung piles were used to supplement information from areas where no direct observations were scored. This study provides the first account of abundance of forest antelopes from the Udzungwa Mountains and confirms that methodological problems — such as poor antelope detectability through understorey vegetation and difficulties of identify antelopes species — are inherent when attempting to estimate density of forest antelopes from line transect counts. Combining counts of signs to direct counts increases the information on some species and comparable data show that camera-trapping can also greatly supplement information, especially for more elusive and/or more nocturnal species.

KEY WORDS: line transects, census walks, density estimates, duikers, forest antelopes, Udzungwa.

Introduction	000
Material and methods	000
Results	000
Discussion	000
Acknowledgements	000
References	000

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INTRODUCTION

Information on population abundance of duikers (*Cephalophus* spp.) and other forest antelopes from the rain forests of the Eastern Arc Mountains, Tanzania, are extremely scant, especially when compared to those available for congeneric species from forest blocks in central, west and south Africa (FEER 1989, BOWLAND & PERRIN 1994, WHITE 1994, STRUHSAKER 1997, LANNOY et al. 2003). Yet, the Eastern Arc Mountains are of global importance for their diversity and high number of endemic species (LOVETT & WASSER 1993, BURGESS et al. 1998, MYERS et al. 2000). The Udzungwa Mountains (10,000 km²; centred on 8°20'S, 35°50'E) comprise the southernmost and largest forested area of the Eastern Arc Mountains. The diverse mammal fauna of the Udzungwa Mountains includes at least five sympatric forest antelopes, making it the most important site in Tanzania for this group (RODGERS & HOMEWOOD 1982, DINESEN et al. 2001).

Previous studies of forest antelopes in the Udzungwa Mountains were based on surveys that did not focus primarily on forest antelopes (DINESEN et al. 2001, TOPP-JØRGENSEN et al. 2001a, 2001b). An other reason for the general lack of information on this group is that forest antelopes are often difficult to detect during census walks, which may result in the low efficacy of census techniques based on direct sightings (KOSTER & HART 1988, BOWLAND & PERRIN 1994, STRUHSAKER 1997). On the other hand, methods based on indirect signs such as dung and tracks also suffer from methodological problems, such as detection/identification of signs and interpretation of results, particularly the conversion of counts into density estimates (KOSTER & HART 1988, PRINS & REITSMA 1989, PLUMPTRE & HARRIS 1995). We present the results from forest antelope counts through line transect censuses conducted in three areas in the Udzungwa Mountains, complemented by information from dung and track counts. We discuss the potential factors underlying the differences found across sites, and discuss the methodological implications.

MATERIAL AND METHODS

Study areas and data collection

Forest antelope counts were conducted along seven paths (Table 1) located in three forest sites (Fig. 1):

(1) Mwanihana Forest (centred on 7°46'S, 36°43'E; 177 km²), located in the Udzungwa Mountains National Park (1990 km²), that covers the northeastern portion of the Udzungwa Mountains. Mwanihana Forest cover the east-facing escarpment slopes of the National Park, from 300 to 2100 m a.s.l. continuously, and receives mean annual rainfall of 1750 mm estimated at 360 m a.s.l. (LOVETT 1996). Three, 4 km-long east-west line transects were positioned about 6 km apart, to sample a mosaic of habitat types from 300 to 800 m a.s.l., from lowland, deciduous woodland to sub-montane, evergreen moist forest.

(2) Ndundulu Forest (centred on 36°35'E, 07°45'S; 250 km²) is located in the western portion of the West Kilombero Scarp Forest Reserve. This is a submontane and montane evergreen forest (1400-2100 m a.s.l.), with herbaceous clearings and patches of bamboo and high altitude *Hagenia abyssinica* woodland. Two east-west transects (called WKS1 and WKS3) were positioned on cartographic lines of latitude 6 km apart through evergreen forest.

(3) New Dabaga/Ulangambi Forest Reserve (here referred to as NDUFR; centred on 35°55'E, 08°05'S; 37-km²) is a high altitude (1800-2100 m a.s.l.) Forest Reserve consisting of

Table 1.

Details of line transects walked to count forest antelopes in three different forest areas from the Udzungwa Mountains, Tanzania.

Study area	Census line	Length of transect (km)	Altitude (m a.s.l.)	Number of census walks	Gross habitat type and length along the line (km)
Mwanihana Forest	“Camp 3”	4.0	350-1000	13	Miombo woodland (1.5 km), open regenerating vegetation (0.5 km), mature forest (2.0)
	“Mwanihana peak”	4.0	320-585	14	Miombo woodland (1.8 km), mature riverine forest (2.2 km)
	“Sanje”	3.7	330-700	14	Miombo woodland (0.7 km), mature forest (3.0 km)
Ndundulu Forest	WKS1	3.2	1940-2089	11	Mostly montane forest, some open areas with herbaceous vegetation
	WKS3	3.1	1372-1625	9	Mostly mature montane forest, some young forest. Montane forest with large amount of edge
NDUFR	NDU2	3.1	1877-2055	10	Mostly regenerating montane forest
	NDU3	3.1	1784-1992	11	Mostly regenerating montane forest

secondary montane evergreen forest. One linear east-west transect and one U-shaped transect (called NDU 2 and NDU 3) were placed in the south and centre of the reserve, respectively (see MARSHALL et al. in press for exact locations).

All of these forest areas are affected by human encroachment to various degrees. Firewood collectors regularly enter into Mwanihana Forest. Poaching of duikers using snares has been reported in all of these areas. The highest level of encroachment has occurred in NDUFR, and includes animal trapping, hunting, pole-cutting and pit-sawing. These activities have significantly reduced the faunal and floral diversity of the forest (FRONTIER TANZANIA 2001a, 2001b; MARSHALL et al. in press).

Mwanihana Forest transects were walked twice per month from July 2002 until January 2003 by F. Rovero. Ndundulu Forest and NDUFR transects were walked on average once per month during the period January-December 2000 by A.R. Marshall. Field assistants accompanied F. Rovero and A.R. Marshall on all walks, however only observations made by these two researchers are used to avoid interobserver bias. Census lines were walked beginning at 07:00-07:30 hr at an average speed of about 1 km hr⁻¹, recording all sightings of duikers. We did not use auditory detection of duikers because all too often it was not possible to be certain that it was an antelope to be heard, and even less possible to identify the species, or at least to differentiate red duikers from smaller antelopes. For each observation, time, species, individuals, distance from animal to the trail and from animal to the observer, and position of the observer along the transect were recorded. Distances were visually estimated, after training

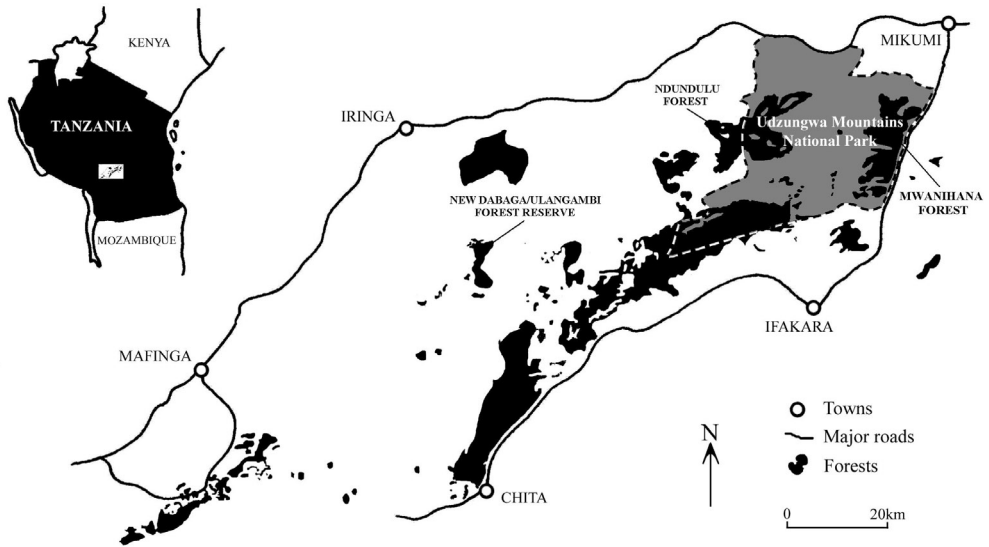


Fig. 1. — Map of the Udzungwa Mountains, Tanzania, showing the three study sites. From MARSHALL et al. (in press).

of both observers through calibration of estimation with actual measures obtained using an optic-meter or a tape measure.

Because of low antelope sighting rates in Ndundulu Forest and NDUFR, counts of dung piles and forest antelope paths (i.e. sets of footprints) were also made in these two areas. Four 1 km transects were placed through evergreen forest in each of NDUFR and Ndundulu Forest. Two of these were positioned within or near to the transects used for census counts, and two positioned elsewhere along equidistant lines of latitude. The number of dung piles within 5 m of each transect and the number of animal paths crossing each transect containing clear forest antelope footprints were recorded.

Available information and preliminary application of camera-trapping (DINESEN et al. 2001, ROVERO et al. submitted) revealed the presence in Mwanihana Forest of Abbott's duiker (*Cephalophus spadix* True 1890), an IUCN Vulnerable and Tanzanian endemic species (EAST 1999, WILSON 2001), red duiker (*Cephalophus natalensis harveyi*; P. GRUBB & J. KINGDON pers. comm.), blue duiker (*Cephalophus monticola* Thunberg 1789) and suni (*Neotragus moschatus* von Dueben 1846). Bushbuck (*Tragelaphus scriptus* Pallas 1766) is also present, probably moving periodically through the study area from and to the western and drier woodland/grassland area. Red duiker and bushbuck are known to occur in Ndundulu Forest and NDUFR; Abbott's duiker and blue duiker are also present in Ndundulu Forest but are either absent or at very low density in NDUFR, probably due to hunting and habitat loss (DINESEN et al. 2001; TOPP-JØRGENSEN et al. 2001a, 2001b). The presence of suni has been confirmed from skeletal evidence in NDUFR (TOPP-JØRGENSEN et al. 2001a) and is also likely to be present in Ndundulu Forest. Bush duiker (*Sylvicapra grimmia* Linnaeus 1758) has not been recorded yet in the forests of the Udzungwa Mountains (e.g. DINESEN et al. 2001), although similarity in coat colour between bush duiker and suni might confound proper identification from sightings unless size can be clearly estimated (ROVERO et al. submitted).

Data analysis

The red duiker could always be identified whilst other antelopes (blue duiker and suni) could not, because of similarity in size. The number of sightings per km walked, defined as

“encounter rate”, was computed as an index of relative abundance (e.g. SEBER 1982). Differences in encounter rate between transects in Mwanihana Forest were tested using Kruskal-Wallis test (SIEGEL & CASTELLAN 1989).

Our number of sightings was much lower than the minimum recommended sample size of 60-80 sightings for density estimation through application of DISTANCE program (BUCKLAND et al. 2001). We therefore applied an alternative method that computes density from the sightings obtained within a fixed strip width (and thus area sampled), based on a truncated sighting distance. Density is given by the ratio: number of sightings scored within the truncated distance divided by the area censused, i.e. length \times width \times 2 sides of transect. We used both animal-trail and animal-observer distances to analyse the relative differences produced in density estimation. Differences between animal-observer and animal-trail distances were tested using Kruskal-Wallis tests. For forest-dwelling primates these differences can be large and the best empirical results have been derived from animal-observer distances (STRUHSAKER 1981, 1997; CHAPMAN et al. 2000). We used the 50% rule to select the cut-off distance as described in CHAPMAN et al. (2000), but also discuss the use of various cut-off distances selected subjectively by inspection of the frequency distribution of distances (see Discussion).

Dung piles and footprints were categorised into small, medium and large sizes (approximately representing blue duiker/suni, red duiker and Abbott’s duiker/bushbuck, respectively). This apportionment of sizes bears the bias of not accounting for young animals (e.g. signs of young red duiker might not be distinguishable from those of adult individuals of smaller antelopes), but we assume that it still gives useful information on the presence of antelopes. In the absence of data on defecation rate and dung/footprint decay rate, moreover, our dung and path counts are only used as a supplementary information to relative abundance obtained from direct sightings.

RESULTS

Red duiker and blue duiker/suni were seen during censuses in Mwanihana Forest, 25 and 4 times, respectively. Abbott’s duiker and bushbuck were never seen. The encounter rates are shown in Table 2, differences for red duikers across the three lines in Mwanihana Forest being not significant (Kruskal Wallis test: $\chi^2 = 1.75$, $df = 2$, $P = 0.42$). No direct sightings of forest antelopes were recorded during census walks in either Ndundulu Forest or NDUFR. Six forest antelopes were heard fleeing during census walks in Ndundulu Forest (one along transect WKS1 and five along transect WKS3), although we did not consider these records in the analysis. Furthermore, counts of forest antelope paths and dung piles in these two latter forests showed that the relative abundance of forest antelopes in Ndundulu Forest far exceeded that in NDUFR (Table 3).

Sightings of red duikers in Mwanihana Forest were pooled for density estimation. Out of 25 sightings, animal-observer and animal-trail distance was estimated for 23 and 19 sightings, respectively, because in the remaining occasions the duiker was seen too quickly and/or in too dense vegetation to determine distance with accuracy. Animal-trail distances were smaller than animal-observer distances (mean \pm standard deviation: 7.7 ± 8.6 and 20.6 ± 6.2 , respectively; Mann-Whitney U Test: $U = 38$, $P < 0.001$). Frequency distribution of sighting distances (Fig. 2) indicate that cut-off distances through the 50% rule are 30 m (including 23 sightings) and 20 m (including 18 sightings) for animal-observer and animal-trail distances, respectively, resulting in density estimations of 2.4 and 2.8 animals km^{-1} , respectively.

Table 2.

Mean values of encounter rate (duikers seen per km walked) for red duiker, *Cephalophus harveyi*, from line transects in Mwanihana Forest, Udzungwa Mountains National Park.

Census line	n	Mean \pm SD encounter rate
1. "Camp 3" trail	10	0.19 \pm 0.10
2. "Mwanihana peak" trail	9	0.17 \pm 0.16
3. "Sanje" trail	6	0.12 \pm 0.20
All Mwanihana Forest trails	25	0.16 \pm 0.17

Table 3.

Mean \pm standard deviation of observations of forest antelope paths and dung piles along transects in Ndundulu Forest (n = 4) and New Dabaga/Ulangambi Forest Reserve (NDUFR; n = 4), Udzungwa Mountains. Significant differences from Mann-Whitney U-tests between Ndundulu Forest and NDUFR transects are shown.

Species	Ndundulu Forest	NDUFR	U	P
Paths per km transect				
Suni/blue duiker	30.50 \pm 17.64	3.50 \pm 2.65	16.0	0.021
Red duiker	23.00 \pm 8.72	3.25 \pm 3.59	16.0	0.020
Abbott's duiker/ bushbuck	14.50 \pm 5.74	0.00	16.0	0.013
Total	60.00 \pm 20.08	6.75 \pm 6.08	16.0	0.021
Dung piles per ha				
Suni/blue duiker	3.25 \pm 2.87	0.00		
Red duiker	4.00 \pm 4.69	0.00		
Abbot's duiker/ bushbuck	2.00 \pm 1.63	0.00		
Total	6.00 \pm 4.83	0.00		

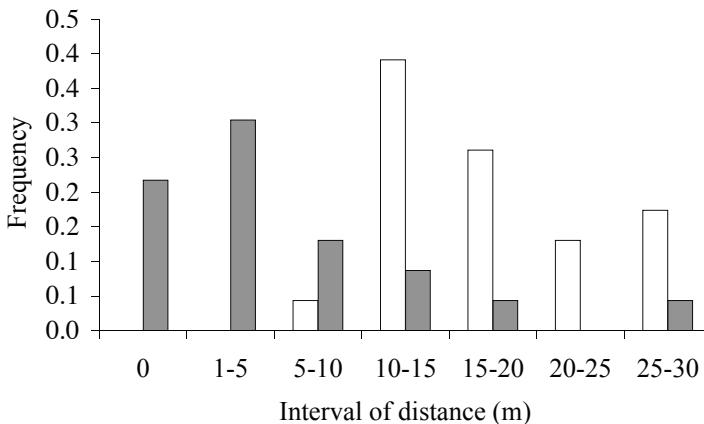


Fig. 2. — Frequency distribution of sighting distances (animal-observer distance: white bars, animal-trail distance: grey bars) of red duikers *Cephalophus natalensis harveyi* during counts from line-transect in Mwanihana Forest, Udzungwa Mountains.

DISCUSSION

Comparing results across the three areas suggests that while red duiker could be regularly seen from line transect walks in Mwanihana Forest this method proved inadequate for other species and other areas, at least from the number of replicates conducted in this study. The low density, elusive behaviour, and more crepuscular and nocturnal habits of some species might be the main reasons for the results obtained. In particular, this could apply to the suni: camera-trap data show that only 28% of 28 photographs of this antelope were taken in day time during a survey of 197 trap-days conducted in Mwanihana Forest (ROVERO et al. submitted). Information on the Abbott's duiker are scant but camera trapping data indicate that this species could be in very low density (EAST 1999, DINESEN et al. 2001, ROVERO et al. submitted). Data on dung and path counts, however, suggest that, especially for Ndundulu Forest where the number of antelope signs is relatively high, factors such as dense understorey vegetation that results in poor visibility might also play a role in lowering detection of forest antelopes. This has been suggested for other forest antelope studies (e.g. KOSTER & HART 1988, BOWLAND & PERRIN 1994) and STRUHSAKER (1997) uses data from Kibale Forest, Uganda, to suggest that differences in visibility and flight response of duikers in relation to understorey vegetation would bias density estimates and therefore affect comparisons across sites. Future data collection should include dung and path counts for all sites being compared, as our lack of such data-set for Mwanihana do not allow to compare between sites the effect on sighting rates of visibility through vegetation and elusive behaviour of antelopes. This latter factor might be particularly important in the heavily encroached NDUFR.

In general, the forest floor vegetation cover was denser in the higher, evergreen and sub-montane portions of the three transects in Mwanihana Forest and throughout the four evergreen and montane transects at NDUFR and Ndundulu Forest. Differences in visibility could also explain some of the variation in the occurrence of red duiker in Mwanihana Forest. In particular, 40% of sightings were within dry, lowland miombo woodland with open forest floor, that accounts for only 20% of the total length of transect lines. Additionally, since miombo woodland is found along the initial portion of transect lines, the higher encounter rates of red duiker might also reflect higher activity during early morning when sampling across this habitat occurred. It is therefore possible that a combination of habitat preference of red duiker for deciduous areas, visibility and time of sampling explain the results reported for Mwanihana Forest. An additional factor to be considered when comparing results across sites is the difference in path width between sites. Paths were wider in Mwanihana Forest (range 1-3 m) than in the other two sites (about 1 m), and may have increased the detection rate in the former site, due to increased visibility and possible selective use of clear walkways by the animals (see STRUHSAKER 1997 and below).

Despite the methodological complications, we suggest that the higher abundance of antelopes recorded during censuses in Mwanihana Forest than in NDUFR and Ndundulu Forest is likely to reflect actual differences in density. Interobserver bias seems unlikely to explain such extreme differences. It is rather more likely that a combination of habitat features, such as vegetation cover, altitudinal range, forest area, and human encroachment is responsible for the differences observed. NDUFR is a small and isolated forest fragment in close proximity to several villages.

Because of this, habitat loss and degradation due to past commercial logging and poaching have been reported in NDUFR, relative to the other sites (MARSHALL et al. in press). Poaching occurs in Mwanihana Forest, but is likely to have had a lower impact on the wildlife because of greater legal protection and patrolling. Studies from other forest sites in Africa have similarly shown that logging and hunting have severe effects on the density of forest antelopes (DUBOST 1979, STRUHSAKER 1997, NOSS 1998, HART 2000).

Differences in vegetation cover and diversity do also occur across sites as a result of altitude and other geographical characteristics, as Mwanihana Forest is low to medium altitude site, NDUFR is high-altitude site and Ndundulu Forest is medium to high altitude site. It is therefore likely that antelope density differences exist because of differences in the abundance and diversity of trees producing fruits and seeds that form the diet of duikers and other antelopes, as suggested in other studies (e.g. HART 1985, NEWING 2001). Our data on relative abundance are consistent with this consideration, since high diversity of trees is reported for Ndundulu Forest relatively to NDUFR (MARSHALL et al. in press) and transects in Mwanihana Forest cross a large variety of habitat types and with high tree species diversity.

The mean encounter rate of 0.16 animals per km walked for red duiker in Mwanihana Forest appears comparable to those recorded with the same methods for other red duiker species from other forest sites e.g. Natal, South-Africa (0.07-0.80, BOWLAND & PERRIN 1994) and south-east Gabon (0.28 pooling five species of red duikers, LANNOY et al. 2003). Encounter rates in Kibale, Uganda, in unlogged and lightly logged compartments range from 0.17 to 0.47 (STRUHSAKER 1997), but these include auditory detection of duikers and are not therefore directly comparable. Data from other areas are even less comparable because they use different methods or pool more than five species (see resume in WHITE 1994, STRUHSAKER 1997).

Estimation of absolute density for red duiker in Mwanihana Forest gave slightly higher values when using animal-trail distance than animal-observer, similar to results from primate line transect censuses (STRUHSAKER 1981). This difference is amplified when more conservative cut-off rules are applied. For example, since 79% of sightings occurred within 10 m off the line and 63% within 5 m (see Fig. 2), realistic cut-off animal-trail distances could also be 10 m and 5 m, generating density of 4.7 and 7.5 animals per km², respectively. In absence of data on "true" densities, it is difficult to assess which method is most correct. However, the study supports STRUHSAKER's (1997) suggestions that since duiker might actively select trails (PAYNE 1992, MCCOY 1995) the use of animal-trail distance would over-estimate densities in comparison to using animal-observer distance.

In conclusion, this study provides the first account of relative abundance of forest antelopes from the Udzungwa Mountains. The study also confirms that methodological problems are inherent when attempting to estimate density of forest antelopes from line transect counts. That this method failed to detect antelopes in two out of three study sites suggests that, overall, line transects are unreliable when there occur a combination of poor visibility through the vegetation, as often applies to rain forests, and elusive behaviour of antelopes due to hunting pressure. Combining counts of signs to direct counts greatly increases the information on some species or group of species and might compensate for detection problems in dense vegetation. Comparable camera-trapping data can also supplement information, especially for elusive and nocturnal species. It is therefore suggested, in line with

previous studies (e.g. KOSTER & HART 1988, BOWLAND & PERRIN 1994, SILVEIRA et al. 2003) that a combination of techniques should be adopted depending on the habitat and species being studied. Further research, moreover, is needed to assess causes of variations in antelope community composition and species' abundance recorded across sites, as our data-set do not allow to evaluate the relative importance of hunting, logging and other habitat features such as altitude. The independent evaluation of the effect of each of these factors on antelope abundance will require ad-hoc positioning of transect lines across study sites.

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