

Notes on Abbott's duiker (*Cephalophus spadix* True 1890) and other forest antelopes of Mwanihana Forest, Udzungwa Mountains, Tanzania, as revealed by camera-trapping and direct observations

F. ROVERO¹, T. JONES² and J. SANDERSON³

¹ Sezione di Zoologia dei Vertebrati, Museo Tridentino di Scienze Naturali, Via Calepina 14, I-38100, Trento, Italy

² Udzungwa Mountains National Park, P.O. Box 99, Mang'ula, Tanzania

³ Center for Applied Biodiversity Science, Conservation International, 1919 M Street, NW, Suite 600, Washington, DC 20036-3521, USA

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The Udzungwa Mountains of south-central Tanzania are part of an internationally outstanding area for biodiversity. This is reflected in the mammalian fauna and particularly in the forest antelopes: at least five species co-exist, including the Tanzanian endemic Abbott's duiker (*Cephalophus spadix* True 1890). Information on forest antelopes from Mwanihana Forest, one of the largest forest blocks within the Udzungwa Mountains, was collected by means of camera-traps and field observations. Eighty photographs of four antelope species were collected during 197 trap-days from four camera-trap sites. Seventy-one sightings were recorded during systematic counts and random survey walks for a total of 150 days of fieldwork. Results include the first photographs in the wild of Abbott's duiker, with one individual caught while holding what appears to be a frog in its mouth. The most photographed and sighted species was the Harvey's duiker (*Cephalophus natalensis harveyi* Thomas 1893), followed by the suni (*Neotragus moschatus* von Dueben 1846). Least photographed were Abbott's duiker and bushbuck (*Tragelaphus scriptus* Pallas 1766). The study shows the usefulness and potential of camera-traps to collect information on the presence, relative abundance and habits of antelopes in densely forested areas.

KEY WORDS: Abbott's duiker, duikers, forest antelopes, camera-trapping, Udzungwa, rain forest.

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¹ Corresponding author: Francesco Rovero (Tel. +39 349 5970234; Fax +39 461 270376; E-mail: francesco.rovero@mtsn.tn.it).

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INTRODUCTION

The Udzungwa Mountains of south-central Tanzania (10000 km²; centred on 8°20'S, 35°50'E) represent the southernmost and largest block of the Eastern Arc Mountains, an area of international importance for the conservation of biodiversity (RODGERS & HOMEWOOD 1982, BURGESS et al. 1988, MYERS et al. 2000). The Eastern Arc Mountains are of major biogeographical interest because of the great age, isolation and fragmented nature of the mountains. These characteristics, combined with the presumed persistence of forest cover over a very long time period, have produced remarkably high levels of endemism and diversity (RODGERS et al. 1982, LOVETT & WASSER 1993). Spanning 300 to 2600 m a.s.l., the forest cover of the Udzungwa Mountains includes primary lowland, mid-altitude (transition), sub-montane, montane, and sub-alpine forest, interspersed with large areas of grassland and "miombo" woodland. There are also large areas of lightly to heavily exploited and degraded forest and grassland (DINESEN et al. 2001, MARSHALL et al. 2005).

The unique biodiversity of the Udzungwa Mountains is well represented in its mammalian fauna (KINGDON & HOWELL 1993). This is particularly so for forest antelopes, of which there are at least five species, making the Udzungwa Mountains the richest site in Tanzania for this group (RODGERS & HOMEWOOD 1982). Among these species is Abbott's duiker (*Cephalophus spadix*), a Tanzanian endemic, forest-dependent species, listed by the IUCN as Vulnerable (CEPF 2002), and known from only four other forested sites (Mount Kilimanjaro, Usambara Mountains, Uluguru Mountains, and Mount Rungwe; EAST 1999, WILSON 2001, MOYER 2003).

The scanty information on forest antelopes of the Udzungwa Mountains derives from zoological surveys that did not primarily focus on forest antelopes (e.g. DINESEN et al. 2001, TOPP-JØRGENSEN et al. 2001). Because of considerable variation in the coat colour of red duikers of the Udzungwa Mountains and the lack of museum specimens, the taxonomy of this species was uncertain (SWYNNERTON & HAYMAN 1951, P. GRUBB pers. comm.). Moreover, the low density of some species, such as Abbott's duiker, the crepuscular and nocturnal habits of some species, and the difficulties of identifying similar species in the field [e.g. suni (*Neotragus moschatus*) and blue duiker (*Cephalophus monticola* Thunberg 1798)] have made it difficult to collect adequate data, even from line transect counts (ROVERO & MARSHALL 2004). The small amount of information available indicates that Abbott's duiker and other forest antelopes are seriously threatened across their range by poaching, habitat loss, and habitat degradation (KINGDON 1997, EAST 1999, MOYER 2003).

This paper presents the results of camera-trapping conducted in Mwanihana Forest, Udzungwa Mountains National Park, with particular emphasis on the first photos in the wild of Abbott's duiker. We discuss the potential of camera-trapping to identify guilds and to study the relative abundance and ecology of forest antelopes, this information being of crucial importance to the proper monitoring and conservation management of these species (PLOWMAN 2003).

MATERIAL AND METHODS

Study area

We conducted the study in Mwanihana Forest (177 km²), Udzungwa Mountains National Park (about 2000 km², centred on 7°46'S 36°43'E). The Park covers the northern portion of the Udzungwa Mountains (Fig. 1). Mwanihana Forest is situated on the slope of the east-facing escarpment and has continuous forest from 300 m to 2100 m a.s.l. Mean annual rainfall is ca 2000 mm.

The diverse mammalian fauna of Mwanihana Forest includes the forest antelopes mentioned in the Introduction and the bushbuck (*Tragelaphus scriptus*). The blue duiker is rarely seen in Mwanihana Forest (T. STRUHSAKER pers. comm.). The bush duiker (*Sylvicapra grimmia* Linnaeus 1758) might be present in deciduous areas but it is not reported from surveys in the forests (DINESEN et al. 2001, TOPP-JØRGENSEN et al. 2001). Among the other large mammals present are African elephant (*Loxodonta africana* Blumenbach 1797), African buffalo (*Syncerus caffer* Sparrman 1779), bush pig (*Potamochoerus larvatus* Cuvier 1822), lion (*Panthera leo* Linnaeus 1758), leopard (*Panthera pardus* Linnaeus 1758), and the spotted hyena (*Crocuta crocuta* Erxleben 1777). Among the primates, the endemic Udzungwa red colobus (*Procolobus gordonorum* Matschie 1900) and Sanje mangabey (*Cercocebus sanjei* not yet formally described) are present, together with black and white colobus (*Colobus angolensis* Sclater 1860), Syke's monkey (*Cercopithecus mitis* Wolf 1822) and yellow baboon (*Papio cynocephalus* Desmarest 1820).

Cameras and trapping sites

We used 6 infrared, heat-in-motion camera units (2 made by CamTrak South Inc., Watkinsville, Georgia, USA, and, subsequently, 4 made by Trailmaster, Goodson and Associates,

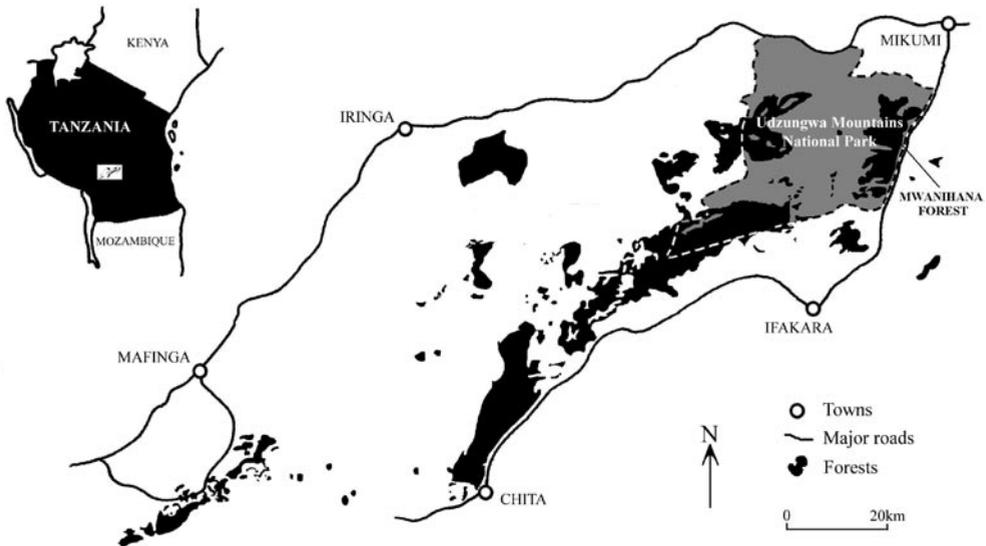


Fig. 1. — Map of the Udzungwa Mountains, Tanzania, showing Mwanihana Forest in the northeastern portion of the mountain range, where the present study was conducted (from MARSHALL et al. 2005).

Inc., Lenexa, Kansas, USA) that were set to take pictures 24 hr per day on 200 ASA colour print film, with a 20 to 30-sec delay between exposures. The date and time of each exposure were shown on the film. We firstly operated camera-traps (CamTrak model) from July until September 2002, for a total of 126 trap-days (64 and 62 for Site 1 and Site 2, respectively). We subsequently operated four cameras (Trailmaster model) in December 2003, for a total of 71 days (23, 18, 18, and 12 for Site 1 to Site 4, respectively). The different sampling effort obtained among camera-sites during December 2003 was due to heavy rain, which damaged some camera units. A 1 m-long measuring stick, with coloured marks at 10 cm-intervals, was placed at the camera-site during the second sampling period. This provided a measure reference on most photos.

We selected trapping sites based on previous sightings of animals, and by surveying the forest floor for wildlife trails. Abbott's duiker, in particular, was sighted previously by T. Jones in the proximity of Site 1. The four sites were also selected because they grossly represent a variety of habitat, with respect to canopy and understorey vegetation cover, within the extremely heterogeneous mosaic of this area. The direct distance between any two camera-sites was 520 to 860 m. Dominant trees in the area are *Parinari excelsa*, *Celtis gomphophylla*, *Bombax rodhagnaphalon*, *Lettowianthus stellatus*, *Tabernaemontana pachysiphon*, *Tarenna pavettoides*, *Ficus* sp., *Dracaena mannii*, *Anthocleista grandiflora* and *Macaranga capensis*.

Site 1. Camera 1 was located on a steep (45°) NE-facing slope, facing a narrow wildlife trail close to a fast-flowing stream (07°48'20.4"S 36°51'15.3"E, 785 m a.s.l.). There is a mix of open areas with scattered small trees and shrubs, and small patches of mature and regenerating forest to 30 m. The forest floor is covered by a low, thin layer of grasses and ferns to 40 cm, with scattered saplings.

Site 2. Camera 2 was located on a well-used wildlife trail, close to a stream, in the bottom of a small, secluded valley that runs from South to North (07°48'17.1"S 36°51'05.3"E, 815 m a.s.l.). The covering of the forest floor is sparser than at Site 1, comprising mostly saplings of *P. excelsa*, with short and scattered herbs and grasses to 1 m. In the valley bottom, there is a seasonally inundated marshy area, with a dense cover of herbs and grasses to 3 m, including *Aframomum* sp. and *Costus* sp.

Site 3. Camera 3 was located on a well-used wildlife trail running on top of a ridge that runs from North to South (07°47'57.1"S 36°51'20.2"E, 810 m a.s.l.). The ridge separates a mature forest from a very steep area with scattered trees and grass cover to 2 m. The forest floor at the camera-site is relatively open and mainly dominated by scattered saplings.

Site 4. Camera 4 was located on another ridge running East to West (07°48'28.0"S 36°51'00.3"E, 770 m a.s.l.). The forest is mainly regenerating with few emergents and dense understorey trees (mainly *Tabernaemontana* spp.) to 5-10 m. The forest floor is also densely covered in tangled lianas and saplings.

Photographs were analysed according to trap-site, species, and date and time of capture (KARANTH & NICHOLS 1998). "Captures" refer to the number of times each species was photographed. We did not score any instances where an individual was captured by the same camera more than once within 24 hr starting at midnight (i.e., where it was likely that it was the same individual; TROLLE & KÉRY 2003). This time interval compromises between the likelihood of multiple scoring of the same individual and the likelihood of missing individuals. In one case, there were two suni captured together: this photograph received two scores. However, with the exception of the bushbuck, we could not distinguish most individuals with certainty. Thus, different captures do not imply different individuals. "Capture rate" is the number of captures divided by the number of trap-days per site. Data from the two sampling periods were pooled.

Also reported here are complementary data from direct and indirect observations of the antelopes and of one of their potential predators, the leopard. These were made by F. Rovero

and T. Jones during fieldwork conducted in Mwanihana Forest and primarily focused on diurnal primates during May 2002-April 2003. Sightings by F. Rovero were recorded during census walks (see ROVERO & MARSHALL 2004 for more details), while sightings by T. Jones were randomly recorded while following and observing Sanje mangabeys.

RESULTS

The trapping periods produced 80 captures of four antelope species (Table 1). The red duiker was identified as Harvey's duiker [*Cephalophus natalensis harveyi* (P. GRUBB & C. GROVES pers. comm.) or *C. harveyi* (J. KINGDON pers. comm.)]. Harvey's duiker was captured most frequently (53% of captures), followed by suni (35% of captures). Abbott's duiker and bushbuck were each captured only 4 and 6 times, respectively. Some photographs of suni from the first sampling period were ambiguously identified as either suni or bush duiker, because of similarities in the coat colour between the two species. Clear identification of these photographs as suni was possible from the subsequent sampling, since the measuring stick placed at the camera sites allowed us to estimate that this antelope had a maximum body height of 30-35 cm, as reported for suni (e.g. KINGDON 1997). The presence of suni and the

Table 1.

Summary of photo-trapping results for forest antelopes taken by two camera-traps in Mwanihana Forest, Udzungwa Mountains, Tanzania (n = 80).

Species	Captures ¹ (Capture rate) ²			
	Site 1	Site 2	Site 3	Site 4
Harvey's duiker (<i>Cephalophus natalensis harveyi</i>)	5 (17.4)	33 (2.4)	0 (NA)	4 (3)
Suni (<i>Neotragus moschatus</i>)	8 (10.8)	7 (11.4)	5 (3.6)	8 (1.5)
Abbott's duiker (<i>Cephalophus spadix</i>)	4 (21.7)	0 (NA)	0 (NA)	0 (NA)
Bushbuck (<i>Tragelaphus scriptus</i>)	0 (NA)	3 (26.6)	3 (6)	0 (NA)

¹ Number of times an antelope passed in front of a camera-trap site, scoring only one case when the same individual was photographed more than once within 24 hr starting at midnight (see Material and methods). ² Trap-days/captures; n = 87, n = 80, n = 18, n = 12 trap-days, for Site 1 to 4, respectively.

Table 2.

Times of day (and frequency) during which antelopes were photographed in Mwanihana Forest, Udzungwa Mountains, Tanzania (n = 80).

Species	Diurnal (7:00-18:00hr)	Crepuscular (6:00-7:00hr, 18:00-19:00hr)	Nocturnal (19:00-6:00hr)
Harvey's duiker	30 (0.71)	9 (0.21)	3 (0.07)
Suni	8 (0.28)	8 (0.28)	12 (0.43)
Abbott's duiker	0 (NA)	1 (0.25)	3 (0.75)
Bushbuck	0 (NA)	1 (0.16)	5 (0.83)



Fig. 2. — Photograph of Abbott's duiker taken by a camera-trap in Mwanihana Forest, Udzungwa Mountains, Tanzania: (above) full animal, (bottom) enlargement of the head, the mouth holding what appears to be a frog.

absence of bush duiker in the forest parts of the Udzungwa Mountains fit with a number of recent observations by F. Rovero and T. Jones, and with previous surveys (L. DINESEN pers. comm., DINESEN et al. 2001, TOPP-JØRGENSEN et al. 2001). While the sample sizes are too small to allow meaningful statistical analysis, the frequen-

Table 3.

Number of forest antelope sightings (frequency) from line transect censuses ($n = 14$ censuses of 3 transects) and random walks ($n = 109$ days of surveys) conducted in Mwanihana Forest, Udzungwa Mountains, Tanzania. The last column summarizes camera-trapping captures (frequency) from the same area (see Table 2 for details).

Species	Sightings		Camera-trap
	Transect censuses	Random walks	
Harvey's duiker	25 (0.86)	42 (0.92)	42 (0.53)
Suni ¹	4 (0.14)	2 (0.04)	28 (0.35)
Abbott's duiker	0 (NA)	2 (0.04)	4 (0.05)
Bushbuck	0 (NA)	0 (NA)	6 (0.07)

¹ Species not identified with certainty during transect censuses and random walks.

cies with which the four species were captured differed among sites. Abbott's duiker was captured only at Site 1, bushbuck only at Site 2 and 3, Harvey's duiker at three of the four camera-sites, with higher frequencies at Site 2 and 4. Suni was captured at all sites, with higher frequencies at Site 3 and 4 than 1 and 2. The times of day at which antelopes were photographed also differed (Table 2), as Harvey's duiker appears to be mainly diurnal and crepuscular (92% of captures), while the suni seems primarily nocturnal and crepuscular (72% of captures). Abbott's duiker and bushbuck were never photographed in daytime. One of the photographs of Abbott's duiker is presented in Fig. 2a-b (full animal and enlargement of head). The individual shown in the picture is of particular interest because it has in its mouth what appears to be a small animal, possibly a frog (see Discussion).

Out of a total of 29 sightings of duikers made by F. Rovero in Mwanihana Forest during 41 census walks conducted along three 4 km-long transects, crossing various habitat types from deciduous woodland (300-500 m a.s.l.) to sub-montane forest (500-800 m a.s.l.), Harvey's duiker was seen 25 times (86%, Table 3). Smaller duikers which could not be identified with certainty (probably suni) were seen on four occasions (14%), while Abbott's duiker and bushbuck were never seen. During 109 days of survey work conducted by T. Jones between 6:00 and 19:00 hr, in an area of Mwanihana Forest that included the four camera-sites, out of 46 sightings of antelopes, Harvey's duiker was sighted on 42 occasions (92%) throughout the day, while smaller duikers (probably suni) and Abbott's duiker were each seen on two occasions between 11:00 and 16:00 hr (Table 3).

Evidence of duiker predation, primarily by the leopard, has been recorded on a number of occasions. The decomposing remains of a Harvey's duiker (P. GRUBB pers. comm.) were found by T. Jones 50 m from camera-trap Site 2, with only the stomach and a section of the hindquarters eaten. Hair and bone fragments probably belonging to Abbott's duiker (P. GRUBB pers. comm.) were found by T. Jones in leopard faeces 150 m from Site 1. Hair and hoofs tentatively identified as belonging to a young Abbott's duiker (P. GRUBB pers. comm.) were also recovered from the large dung heap of a large carnivore, in between the two camera-sites (T. STRUHSAKER pers. comm.).

DISCUSSION

A remarkable set of photographs of forest antelopes was obtained in this study, despite using only four cameras simultaneously and for a total of 197 trap-days. The relatively high number of photographs of Harvey's duiker, although it is not possible to know the number of individuals, seems comparable to the high encounter rates obtained from diurnal sightings recorded during random observations and systematic counts (Table 3), and is also in line with previous accounts (DINESEN et al. 2001). This comparison is more difficult for the suni, since this antelope seems to be more crepuscular and nocturnal, reducing its chance of being encountered by humans. However, suni is reported to be widespread across a wide range of habitats, including low-altitude woodlands in the Udzungwa Mountains (EAST 1999). While recent studies have shown the potential of using camera-trapping rates as approximations of relative abundance even when individuals cannot be identified (CARBONE et al. 2001, O'BRIEN et al. 2003), our small data-set does not allow for such analysis. This will require a greater camera-trapping effort and correlation of trapping rates with density estimates derived from line transects placed in the same area. Nevertheless, camera-trapping is confirmed as a useful tool to obtain information on nocturnal and elusive species, while line transects appear most useful for censusing diurnal and readily identifiable species (ROVERO & MARSHALL 2004).

The small number of photographs and sightings of Abbott's duiker and bush-buck suggest that these species are either present in low densities or that the two sites sampled comprise unsuitable or marginal habitat. Similar considerations might also apply to the blue duiker, which was neither photographed nor sighted with certainty during this study, but is known to occur in Mwanihana Forest (T. STRUHSAKER pers. comm.). Thus, while our results provide preliminary indications on presence and activity patterns of Harvey's duiker and suni, more extensive sampling will be necessary to draw broader conclusions concerning these and other antelope species. Similarly, little consideration can be drawn from the differences in capture frequency of antelopes among sites. Suni and red duiker appear to be widespread in different types of habitat, while the capture of Abbott's duiker only at Site 1 might indicate preference for steep areas and dense understorey habitats.

Abbott's duiker was photographed for the first time in the wild. The Abbott's duiker shown in Fig. 1 is probably holding in its mouth an amphibian, possibly a Tanzanian torrent frog (*Arthroleptis yakusini*) (M. MENEGON pers. comm.). This conclusion is based on a number of considerations: the estimated body length of the frog (6-8 cm), the symmetry and structure of what appear to be hindlegs, the appearance of a foreleg at the base of the mouth, and the shining mucus on part of the skin. The Tanzanian torrent frog lives in small, rocky streams (CHANNING et al. 2002, M. MENEGON pers. comm.), as found at the site where this photograph was taken (Site 1). The sporadic capture of live prey by duikers has already been reported. WILSON (1966) reports on two bush duikers eating Guinea fowl chicks and STONEHAM (1955) reports on a duiker (species not indicated) stalking guinea fowls in Kenya. Both photographs and direct sightings of Harvey's duiker reveal that there is some variation among individuals in the colour pattern of the coat, especially in the extent of black on the legs and dorsal portion of the neck. A comparison of individuals from different forests (i.e. different subpopulations) will be necessary to assess whether these variations are within the range reported for the species.

This study shows that camera-traps are a useful tool to collect much needed information on the presence, taxonomy and habits of forest antelopes, as shown for other elusive mammals living in tropical forests (e.g. HOLDEN et al. 2003, KINNAIRD et al. 2003, NOSS et al. 2003). Further work will be required to adequately assess the potential of camera-trapping to estimate relative abundance. Testing the correlation of camera-trapping rates with density estimates derived from line transects would be of crucial importance in future studies (O'BRIEN et al. 2003). Estimation of rain forest antelope abundance from line transect censuses is fraught with technical difficulties, as summarized in several studies (e.g. KOSTER & HART 1988, BOWLAND & PERRIN 1994, STRUHSAKER 1997) and based on first-hand experience from Mwanihana Forest (ROVERO & MARSHALL 2004). Furthermore, the differences in capture rates across different habitat types and the differences in the times of day at which antelopes were photographed are interesting, suggesting that more extensive sampling with more cameras could facilitate detailed investigation into niche separation, both temporal and spatial, among sympatric forest antelopes.

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