Research Article

Vanishing wildlife corridors and options for restoration: a case study from Tanzania

Trevor Jones[1,2], Andrew J. Bamford[3], Daniella Ferrol-Schulte[3,4], Proches Hieronimo[5], Nicholas McWilliam[2] and Francesco Rovero[6,7]

[1] Udzungwa Elephant Project, Box 99, Mang'ula, Tanzania; [2] Animal and Environmental Research Group, Anglia Ruskin University, East Road, Cambridge, CB1 1PT UK; [3] Society for Environmental Exploration, 50-52 Rivington Street, EC2A 3QP, London, UK; [4] Leibniz Centre for Tropical Marine Ecology, Fahrenheitstrasse 6, 28359 Bremen, Germany; [5] Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, Box 3003, Morogoro, Tanzania; [6] Tropical Biodiversity Section, Museo delle Scienze, Via Calepina 14, 38122 Trento, Italy; [7] Udzungwa Ecological Monitoring Centre, Udzungwa Mountains National Park, Box 99, Mang'ula, Tanzania; Corresponding author: Francesco Rovero E-mail: francesco.rovero@mtsn.tn.it

Abstract

Conserving wildlife corridors is increasingly important for maintaining ecological and genetic connectivity in times of unprecedented habitat fragmentation. Documenting connectivity loss, assessing root causes, and exploring restoration options are therefore priority conservation goals. A 2009 nationwide assessment in Tanzania documented 31 major remaining corridors, the majority of which were described as threatened. The corridor between the Udzungwa Mountains and the Selous Game Reserve in south-central Tanzania, a major link between western and southern wildlife communities, especially for the African elephant *Loxodonta africana*, provides an illuminating case study. A preliminary assessment in 2005 found that connectivity was barely persisting via two remaining routes. Here we present assessments of these two corridors conducted from 2007-2010, using a combination of dung surveys, habitat mapping and questionnaires. We found that both corridor routes have become closed over the last five years. Increased farming and livestock keeping, associated with both local immigration and population growth, were the main reasons for corridor blockage. However, continued attempts by elephants to cross by both routes suggest that connectivity can be restored. This entails a process of harmonizing differing land owners and uses towards a common goal. We provide recommendations for restoring lost connectivity and discuss the prospects for preventing further loss of corridors across the country.

Key words: elephant, connectivity, Udzungwa, Selous, Tanzania

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Introduction

Wildlife corridors are of critical importance for maintaining the viability of isolated populations and conserving ecosystem functionality [1]; for balancing conservation and human development needs in increasingly modified landscapes [2, 3 but see 4]; and for preventing habitat degradation by confined "ecosystem engineer" species such as elephants [5, 6]. Despite this importance, corridors are being lost throughout the world at escalating speed [7-10], and therefore documenting threats to connectivity, assessing the root causes of these threats, and exploring restoration options have become priority conservation goals over the last decade.

In Tanzania, where we conducted the present study, a detailed compilation of known wildlife corridors across mainland Tanzania was completed in 2009 [11]. This is one of only three existing national corridor reports, the other two being from Bhutan [2, 12, 13] and India, the latter focused on elephant corridors [14]. The Tanzanian assessment described 31 corridors, of which 24 (77%) were placed in categories of "extreme" or "critical" condition, meaning that they were predicted to cease being functional wildlife corridors within five years without some form of intervention [10, 11, 15].

Five types of wildlife corridor were identified in Tanzania, including three categories covering areas that were either confirmed or suspected to be active movement routes, but which were data deficient [11]. A fourth category covered proposed or potential corridor areas linking fragmented or threatened habitat patches (usually forest), and the final category was defined by "known animal movement between two protected areas." Among the eight corridors in this final category is an area in southern Tanzania used by large mammals to move between the Udzungwa Mountains and Selous ecosystems, comprising two remaining routes identified in 2005 and named the Nyanganje Corridor and the Ruipa Corridor [16, 17].

Connectivity between the Udzungwa and Selous ecosystems is of special conservation importance for elephants (*Loxodonta africana*). A recent nationwide assessment of elephant corridors [18] suggests that the major elephant populations of Tanzania are genetically interconnected via the movements of breeding individuals through corridor areas. The elephant meta-population of southern Tanzania is globally important, totalling approximately 65,000 individuals, or 47% of East Africa's elephants [18, 19], and spanning the Ruaha-Rungwa, Udzungwa, and Selous-Mikumi ecosystems (Fig. 1), with the Udzungwa-Selous connection as a vital link in this network. Moreover, recent work in southern Tanzania has revealed a highly positive correlation between the presence of elephants outside of protected areas and large mammal diversity [20, 21], confirming the wider benefits for biodiversity conservation of planning for and protecting elephant corridors.

We present the results of a study conducted between 2005 and 2010 aimed at (1) assessing connectivity of large mammal populations of the Udzungwa Mountains and the Selous Game Reserve, (2) documenting connectivity changes over the study period, (3) determining local and regional land use, and (4) using this information to propose a general operational framework for corridor restoration.

Methods

Study Area

The Udzungwa Mountains (or "Udzungwas") of southern Tanzania (>10,000 km^2, of which approximately 1,550 km^2 are forested) have an exceptionally high level of species endemism and richness, making them a priority site for conservation in Africa [22].

Between the Udzungwas and the Selous Game Reserve (SGR) is the Kilombero Valley (6,650 km^2), which consists of a seasonally inundated floodplain [23], designated as a Ramsar site since 2002 and as an Important Bird Area [24]. The valley is home to nationally important but dwindling populations of large mammals including puku (*Kobus vardonii*) [18, 25], and it is known that elephants historically crossed the valley to move between the Udzungwas and the SGR [16].

As one of Africa's largest wetlands, the Kilombero Valley is also prime land for farming, especially of rice and sugar cane [26, 27], and in recent decades local human immigration and associated conversion of wildlife habitats to farmland has been widespread and rapid [16, 26, 28, 29, 30]. An increasing immigration of pastoralists with cattle has also been observed in recent years.

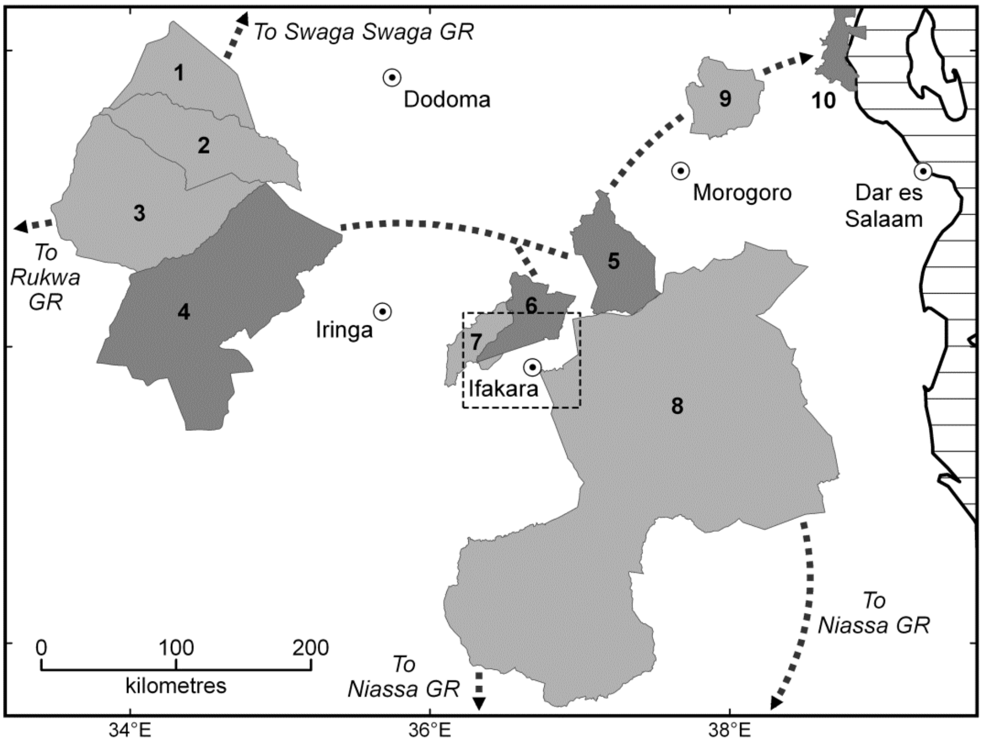

Fig. 1. Map showing major protected areas of south-central Tanzania, and current or recent routes of large mammal movements (dotted lines). (1) Muhezi GR, (2) Kizigo GR, (3) Rungwa GR, (4) Ruaha NP, (5) Mikumi NP, (6) Udzungwa Mountains NP, (7) Kilombero NR, (8) Selous GR, (9) Wami-Mbiki WMA, (10) Saadani NP. Inset shows the extent of Fig. 2. Sources: 11, 20, 21, 22. GR = Game Reserve, NP = National park, NR = Nature Reserve, WMA = Wildlife Management Area.

Identification of Corridors

In 2005-2006, we conducted a feasibility study throughout the Kilombero Valley to evaluate the status of ecological connectivity between the Udzungwa Mountains and Selous ecosystems, using a combination of questionnaires and interviews, dung and disturbance transects, aerial surveys and ground mapping (see 15 for full details). A number of already closed wildlife corridors were reported by local communities, suggesting that connectivity was extensive in the past. By then however, only two functional remaining corridors in the Kilombero Valley were identified (Fig. 2) and preliminarily assessed:

(i) The **Nyanganje Corridor** is situated at a narrow 'bottleneck' of the Kilombero Valley. From the Nyanganje Forest Reserve (69 km^2, centred on 36°47'E, 8°00'S) to the Selous GR, the corridor is approximately 14 km long and 8 km wide, covering 115.2 km^2. Here the valley is a mosaic of scattered farms, degraded grassland, semi-natural grassland, scrub, marsh and scattered patches of woodland.

(ii) The **Ruipa Corridor** (0.5-6 km wide, 20 km long; a total area of ~ 25 km^2) is situated close to the Ruipa river to the southwest of Ifakara town, in the southern Kilombero Valley, and crosses a mosaic of habitats, including riverine forest, woodland, scrub, degraded pasture and swamp. It begins at the large Matundu forest, and heads southeast onto the Kilombero floodplain, crossing a Game Controlled Area (GCA), a commercial teak plantation, and village land, including a newly designated Wildlife Management Area (WMA) along the border of the Selous GR.

Following this initial study, we carried out surveys and assessments along these corridors from 2007 - 2010. A subset of areas within the corridors were sampled more than once, allowing for temporal comparisons.

Data Collection and Analysis

Ecological sampling and assessment involved dung and disturbance transects, land use mapping and classifications. Local community sampling involved questionnaires, informal interviews and consultations (Table 1). Animal presence was recorded on the ground by scoring dung and tracks seen within a width of 2 m while walking transects placed randomly within the corridor and according to sample size in Table 1.

Table 1. Summary of methods and sample sizes of data collected in Nyangange and Ruipa corridors, Tanzania, from 2005-2010.

Method	**Nyanganje 2005/6**	**Ruipa 2005/6**	**Nyanganje 2008-10**	**Ruipa 2007-10**
Aerial survey[1]	√	√		
Dung and disturbance transects: (total km)	21	25	64	494.5
Land use ground-truthing, mapping and classification	√	√	√	√
Questionnaires/Interviews / Consultations (n)	52	65	113	322

[1] WCS Conservation Flight Program

Quantum GIS 1.7.1-Wroclaw was used to map presence of animals and land use within the corridors. For the maps and land cover analysis presented here, we used the most up-to-date available land cover data for the Kilombero Basin, an update of the 1997 Hunting Technical Services dataset by the Valuing The Arc project [31, 32], having verified its accuracy by ground-truthing and by comparison with fine-scale aerial photographs provided by the WCS Flight Conservation Program. More detailed explanations of methods, ground truthing data, and additional results from all surveys are in the relevant reports [16, 33-35].

Nyanganje Corridor

Twelve randomly placed transects of 1.5-2 km each (total 21 km) were walked in the corridors area in September 2006, while eight transects of 1-5 km each (total 28 km) were completed in May and June 2010. Fifty-two local inhabitants of Signali and Sagamaganga villages were interviewed between February 2006 and April 2007, and 109 interviews were carried out in Signal, Sagamaganga and Lungongole in May and June 2010.

Ruipa Corridor

The Namwai forest is a key section of the Ruipa Corridor, because its woodland habitat and diversity of mammal species suggest a refugium role within the corridor [16]. Here we used 2-metre wide strip transects split into 20 metre sections, on which tracks of large mammals were recorded as present or absent in each section. A track score was calculated for each species on each transect as the proportion of sections with tracks present. Three transects, each 1,500 metres long, were monitored every three months throughout 2007 and again in October 2010. Transect surveys were carried out in the area bordering the Selous between 2008 and 2010, where 24 transects of 0.5 km were monitored, and in the game controlled area during July and August 2010, where 3 transects of 5 km were surveyed.

From May to August 2006, 65 questionnaires were completed by inhabitants of the villages of Mofu, Kisegese and Namawala, close to the Namwai forest. In March 2010, 38 questionnaires were completed by inhabitants of Mofu and Kisegese.

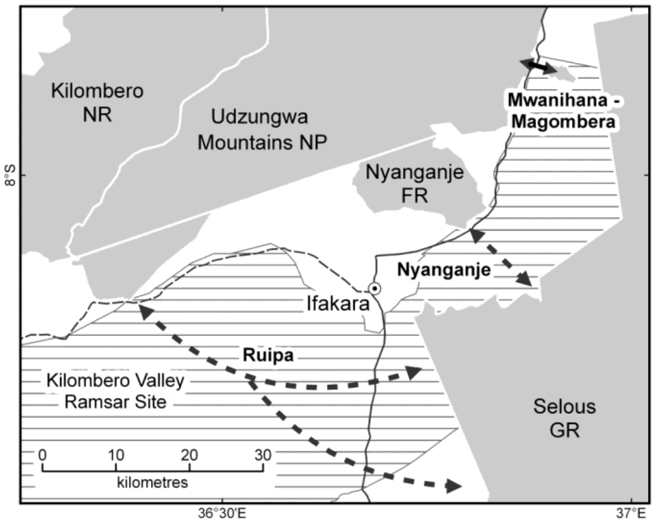

Fig. 2. Map showing approximate locations of Nyanganje and Ruipa corridors linking Udzungwas to Selous Game Reserve in Tanzania, and a potential route of the proposed Mwanihana-Magombera Corridor (see 'Options for restoration of connectivity' in text). GR = Game Reserve, NP = National park, NR = Nature Reserve, FR = Forest Reserve.

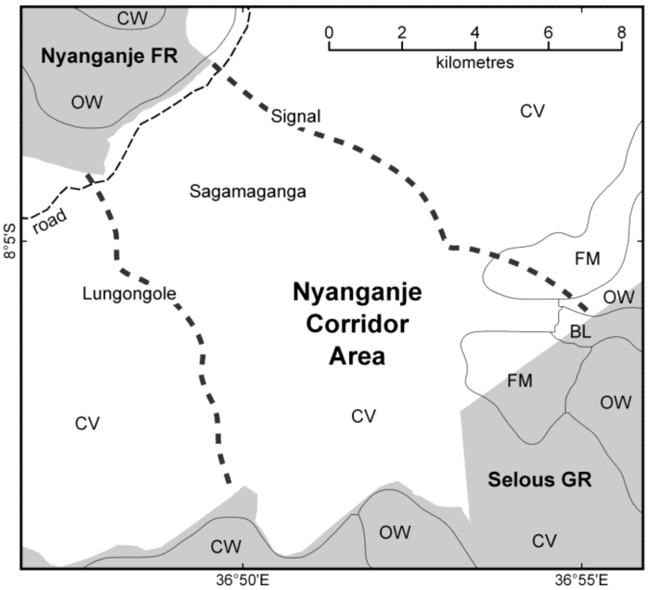

Fig. 3. Map showing land cover and villages of the greater Nyanganje Corridor Area. Land cover classifications: BL = Bushland, CV = Cultivation, CW = Closed Woodland, FM = Forest Mosaic, OW = Open Woodland.

Results

Nyanganje Corridor

Four large mammal species were recorded on transects throughout the corridor in 2006: elephant, buffalo (*Syncerus caffer*), bushpig (*Potamochoerus larvatus*) and yellow baboon (*Papio cyanocephalus*). Eighty per cent of questionnaire respondents in 2006 reported elephants crossing their farms, and 47% reported buffalo (though interestingly, only 29% perceived conflict with wildlife). General perception in 2006 was that elephants were crossing the corridor each year from January to March, while buffalo were moving all year round. Other animals reported from within the corridor area in 2006 included bushbuck (*Tragelaphus scriptus*), leopard (*Panthera pardus*), lion (*Panthera leo*), and puku.

In 2010, in contrast, large mammals were only recorded at the western and eastern ends of the corridor, within 1 km of the boundaries of the Nyanganje FR and SGR, respectively. Elephants were reported as regularly leaving the forest at either end of the corridor, but turning back upon encountering farms. Ninety-eight per cent of respondents in 2010 did not believe that the corridor was functioning any more.

Almost the entire Nyanganje corridor area is classified as cultivation (Fig. 3), and comprises a dynamic landscape of scattered farms – many of them temporary or seasonal – amongst wild scrub and scattered trees. Density of human settlements throughout the corridor area is low. The most challenging area to protect will likely be the area adjacent to the Mikumi-Ifakara road, where there are scattered cultivation and some human-wildlife conflict (though no permanent human settlements). This critical western section of the Corridor is about 3 km long and 0.5-2.5 km wide.

Ruipa Corridor

Results of animal sign transects in Namwai forest (northern Ruipa corridor) showed that between 2007 and 2010 relative abundance of signs declined significantly for all detectable wild mammal species (Signed Wilcoxon test, n=12, V=78, p=0.002). Twenty-five species of large mammal (including buffalo, but not elephants) were recorded during 2007, but only one species (an antelope, probably the red duiker *Cephalophus harveyi*) was detected during October 2010 (though elephant signs were also opportunistically encountered in the same area in May 2010). Conversely, signs of cattle were detected in 100% of transect sections in 2010, compared with 37% in 2007 (Fig. 4).

In 2007, 78% of respondents reported having elephants on their farms and 59% had buffalo, compared with 38% and 10% respectively in 2010. In 2007, buffalo were reported as present in the area all year round, while elephants were crossing between March and May. By 2010, villagers were of the opinion that elephants moved through the area during the rainy season in April and May, but that these movements no longer occurred every year.

No large mammal signs at all were detected in 2010 in the Game Controlled Area. The area bordering the Selous GR contains a far greater diversity of large mammals, with 28 species recorded between 2008 and 2010. Even here, the number of species recorded declined over the 3 years of monitoring (Spearman's rank correlation, r_s=-0.819, P=0.001), from 28 species in 2008 to 23 in 2010.

The Ruipa corridor area is a mosaic of habitat types, with eight classifications of land cover identified (Fig. 5), ranging from closed woodland to cultivation, and including monocrop teak plantations. Stakeholders of this land include 10 villages, the Kilombero Valley Teak Company [36, 37], and the Wildlife Division who co-manage the Game Controlled Area. The majority of the corridor area is within the Kilombero Valley Ramsar site.

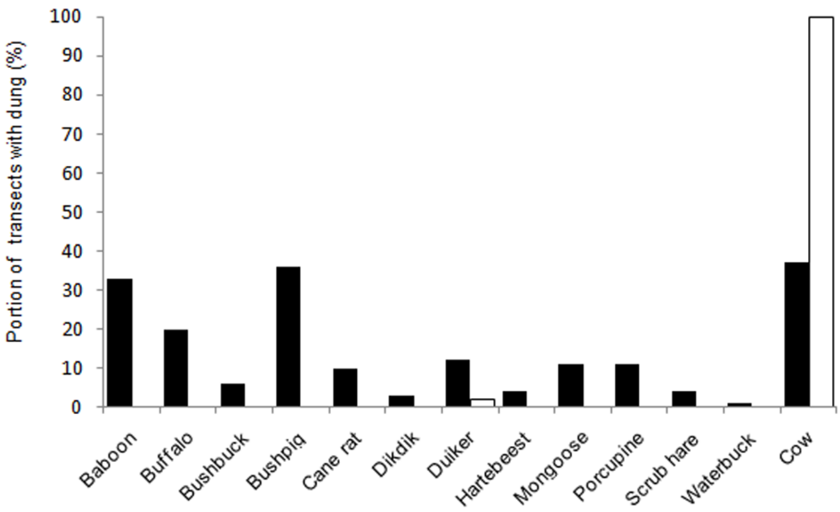

Fig. 4. Changes in abundance of sign of wild mammals and cattle along transects in Namwai forest, northern Ruipa Corridor, Tanzania, between 2007 and 2010. Y-axis shows the percentage of 20-metre sections of transect along which signs of each animal were recorded.

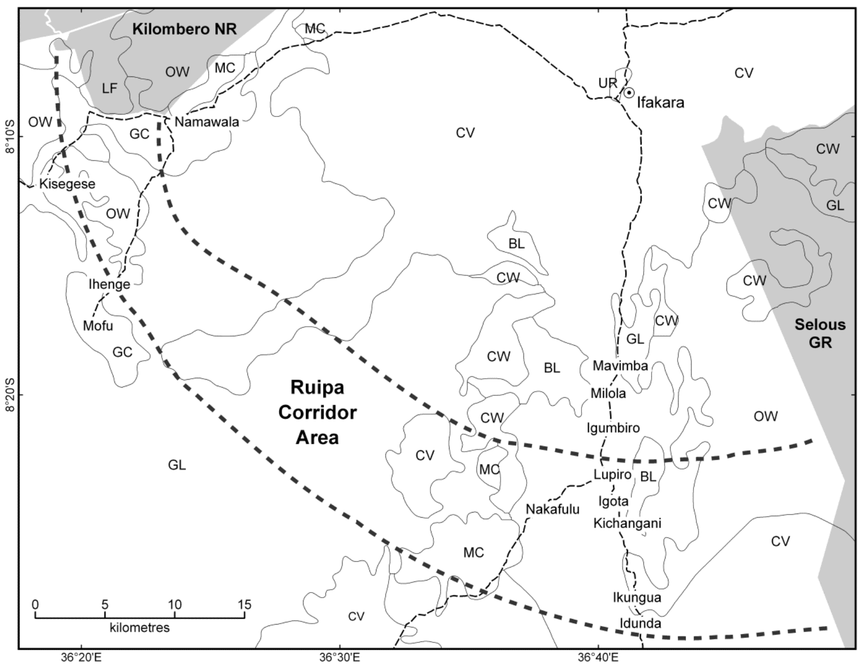

Fig. 5. Map showing the land-cover and villages of the greater Ruipa Corridor Area in Tanzania. Land cover classifications: BL = Bushland, CV = Cultivation, CW = Closed Woodland, GC = Grass with Scattered Crops, GL = Grassland, LF = Lowland Forest, MC = Monocrop (teak plantations), OW = Open Woodland.

Discussion

Vanishing corridors

The most recent surveys (2009-10) suggest that the Nyanganje Corridor has become closed to elephants and other wildlife, most likely due to local human immigration and associated increases in use of land for rice farming and cattle grazing, both of which can have severe effects on wildlife [38]. However, our assessment indicates that the mosaic of habitats, seasonal farming practices, and low level of permanent settlements throughout the corridor make the movements of large mammals between the Udzungwa Mountains and the Selous GR feasible in the future. Elephants have been shown to move rapidly and discretely across 'risk landscapes' [39, 40], in keeping with farmers' reports in 2006 of elephants crossing

Nyanganje corridor rapidly without pausing to feed on crops. In contrast, in 2009-10 several farmers reported to us that crop-raiding by elephants had increased at either end of the blocked route.

Similarly, the significant decline in animal presence between 2007 and 2010 indicates that the Ruipa corridor is currently also not a viable route for migration of large mammals, due to the same causes identified above. Of the various sections in the corridor (see Results), only the eastern area bordering the SGR (which is in the process of becoming a WMA) remains populated by wildlife. Continuing encroachment of farms and cattle into this area threatens to push the wildlife further back towards the SGR. Although villages close to the Selous do have land management plans, we found that these plans were not enforced. It is encouraging, however, that management plans drawn up in 2011 for Kichangani, Ikungua and Idunda villages (Fig. 5) include narrow wildlife corridors, 900-2000 m wide, running east to west (S. Lloyd, pers. comm., February 2012).

Despite the recent blocking of Nyanganje and Ruipa corridors, several residents reported that on both routes elephants are still observed each year attempting to cross from either end. Elephant sign was also recorded in Namwai in May 2010, the first confirmed presence since 2006. Elephants are known to have long memories [41, 42] and may remember old migration routes many years after being denied access to them. Medium-sized ungulates can also resume long-distance migrations if connectivity is restored within a few years [43]. Thus the blocking of these corridors should not be considered irreversible.

Options for restoration of connectivity

The Udzungwa-Selous corridors, as is the case for the majority of Tanzanian wildlife corridors (http://www.tzwildlifecorridors.org), cross human-dominated landscapes with differing land management regimes and legal status. Thus, solutions for corridor protection and management must be accordingly diversified and site-tuned, with community-led land use planning being the primary long-term solution. Indeed, if communities are not involved from the outset, political problems are likely to snowball and the damaging and erroneous perception of corridor conservation as a land-grab may gain ground [4, 44]. Examples from Tanzania, where communities are given sustained technical and logistical support, are encouraging in that they indicate successful local land use planning and implementation for conservation [3, 45]. In addition, the policy framework in Tanzania is conducive to corridor restoration. The 2009 Wildlife Act of Tanzania states that "The Minister may, in consultation with relevant local authorities and by order in the G*azette*, designate wildlife corridors, dispersal areas, buffer zones and migratory routes" [46]. Moreover, the 2010-15 National Elephant Management Plan of Tanzania [18] names Elephant Corridors as its second Strategic Objective, providing a positive conservation agenda for other large mammal species [20].

Figure 6 describes the institutional and operational options that may be considered to protect corridors. A “Corridor Planning Committee”, with representatives of all land owners and users along the entire corridor, should plan coordinated land allocation and use. Among management options to be considered is the private purchase of land not occupied by people; or, if a high priority area has low human density, small numbers of people may be compensated to move. Another approach is the extension of existing protected areas, for example of the Nyanganje FR eastwards, and/or a westwards extension of the SGR. Effective long-term management of these areas will nevertheless require sensitive collaboration with adjacent communities.

Fencing linear sections of a corridor to funnel animals through more heavily farmed areas may also need to be considered [40]. The private sector has a role to play in these aspects of management, as evidenced in the recent successful creation of a highway underpass in central Kenya, which elephants began using within one week of its completion (http://www.savetheelephants.org/diary-reader/items/historic-passage-first-elephant-passes-through-new-mt-kenya-underpass.html). In the Udzungwa area, the northern Kilombero

Valley is dominated by cultivation of sugarcane by the Illovo Sugar Company and outgrowers, including the 6 km area between Mwanihana forest in the Udzungwa Mountains National Park and Magombera forest on the edge of the Selous Game Reserve (Fig. 2). This is the shortest distance between the Udzungwa and Selous ecosystems and elephants are present at both ends, offering the possibility of restoring connectivity via a 6 km long, fenced corridor, involving fewer stakeholders than the other two, more complex corridors.

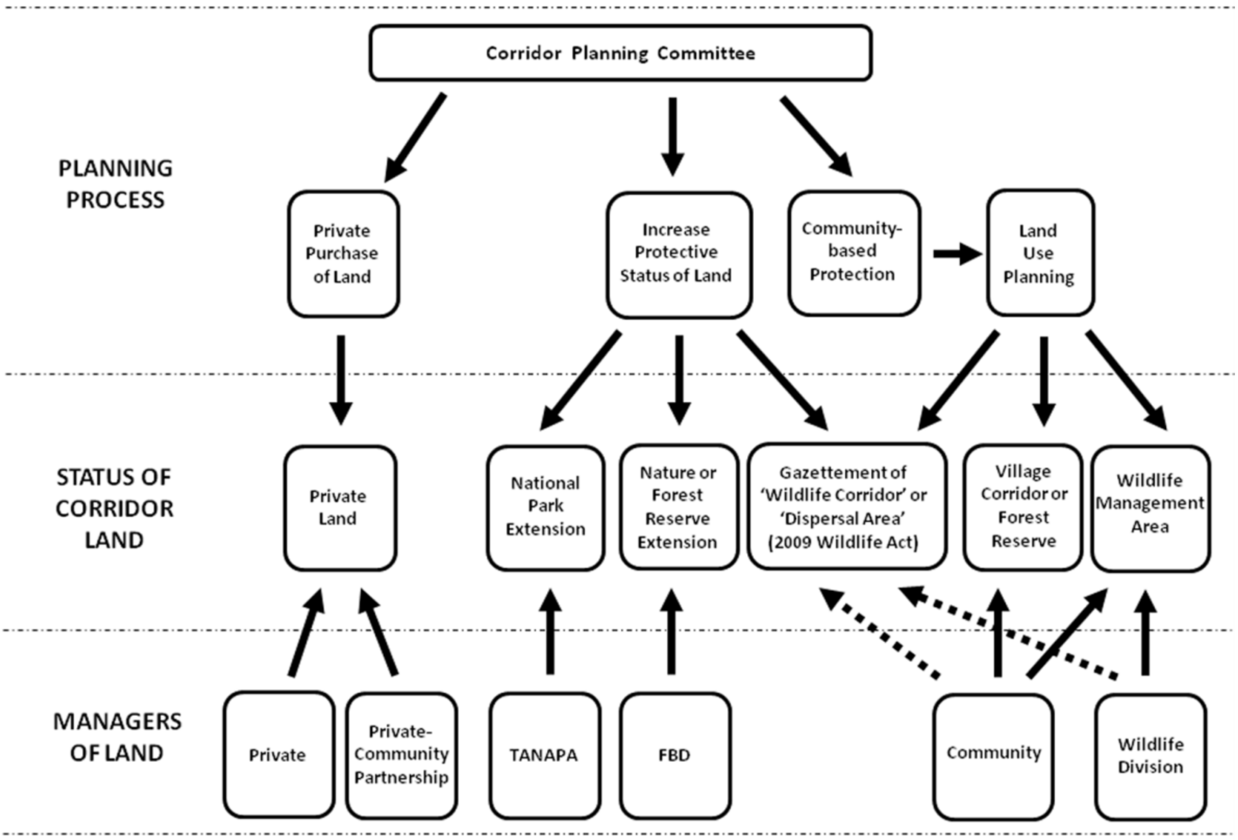

Fig. 6. Scheme of planning and management options for conserving threatened wildlife corridors in Tanzania.

Implications for conservation

A recent meta-analysis of corridor effectiveness supports the importance of maintaining natural corridors versus creating new ones [47]. Corridor restoration will require a combination of site-tuned land-use planning and protection harmonized among various private and public land owners, with resident communities being fully involved. Through the flexible and coordinated approach outlined here, the Nyanganje, Ruipa and Mwanihana-Magombera corridors could be re-opened, thus restoring a critical ecological link for Tanzania.

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