BioOne COMPLETE

Forest Area, Fragmentation, and Loss in the Eastern Arc Mountains: Implications For the Conservation of Biological Diversity

Author: Newmark, W. D.

Source: Journal of East African Natural History, 87(1) : 29-36

Published By: Nature Kenya/East African Natural History Society

URL: https://doi.org/10.2982/0012-8317(1998)87[29:FAFALI]2.0.CO;2

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Journal of East African Natural History **87**: 29–36 (1998)

FOREST AREA, FRAGMENTATION, AND LOSS IN THE EASTERN ARC MOUNTAINS: IMPLICATIONS FOR THE CONSERVATION OF BIOLOGICAL DIVERSITY

W.D. Newmark
Department of Zoology and Marine Biology, University of Dar es Salaam
P.O. Box 35064, Dar es Salaam, Tanzania[1]

ABSTRACT

An understanding of forest area, fragmentation and loss is central to developing strategies to conserve biological diversity in the Eastern Arc Mountains. Using recent 1:250,000 land cover and use maps (Tanzanian Ministry of Natural Resources and Tourism, 1996) and 1:250,000 and 1:500,000 topographic maps, I examine natural forest area, fragmentation, and loss in the Eastern Arc Mountains. I estimate the maximum total area of natural forest, open as well as closed forest, in the Eastern Arc Mountains is 5,340 km^2. The remaining natural forest in the Eastern Arc Mountains is highly fragmented. The median patch size is 10.2 km^2, and the mean patch size is 58.0 km^2. Based upon the estimates of various workers, approximately 1,447 km^2 of closed forest remains in the Eastern Arc Mountains or 27 % of the remaining natural forest. Comparisons of the current to prehistoric forest cover suggest that 77 % of the original forest has been lost over the last approximately 2,000 years.

INTRODUCTION

Forest loss and fragmentation are widely recognised as the two most important factors responsible for loss of biological diversity worldwide (Diamond, 1984; Reid & Miller, 1989; Whitmore, 1997). The Eastern Arc Mountains have suffered extensive forest loss and fragmentation due to human disturbance and fire. While the exact prehistoric or pre-human impact coverage of forest in the Eastern Arc Mountains is unknown, the existence of remnant patches of forest at varying elevations throughout the Eastern Arc Mountains suggests that nearly all of the Eastern Arc Mountains were forested prior to human occupation and disturbance. The presence of iron age sites in the Usambara and Pare Mountains and the Taita Hills indicates that humans have been altering the Eastern Arc forests for at least 2,000 years (Schmidt, 1989). Additionally, archaeological evidence in combination with pollen samples from Burundi, Rwanda, and western Uganda suggests that widespread clearance of forest by humans began in these regions 2,300 years BP (Jolly *et al.*, 1997).

An understanding of the current coverage and distribution of natural forest in the Eastern Arc Mountains is critical for developing strategies to conserve biological diversity. This paper reviews the amount of natural and closed forest in the Eastern Arc Mountains, the size

[1] Current Address: Utah Museum of Natural History, University of Utah, 1390 E. Presidents Circle, Salt Lake City, Utah 84112, USA email: bnewmark@geode.umnh.utah.edu

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

of forest patches, change in forest cover, and the implications of these patterns for conserving biological diversity.

METHODS

I measured with a digital planimeter the natural forest area in the Eastern Arc Mountains in Tanzania from recent 1:250,000 land cover and use maps (Ministry of Natural Resources and Tourism, 1996). Data on forest cover and patch size for the Taita Hills were graciously provided by L. Lens. The Tanzanian land cover and use maps are derived from recent, predominantly 1994–1996, Landsat imagery and include nine major land cover and use types: forest, woodland, closed woodland, bushland, grassland, cultivated land, open land, water features, and other. The forest cover type, in turn, is divided into three sub-cover types: natural, mangrove, and plantation. I also measured on these same land cover and use maps the linear distance between the largest fragments and recorded the land cover and use adjacent to these fragments.

The area of closed forest in each of the Eastern Arc Mountains was calculated by compiling estimates from earlier published accounts and by interviewing knowledgeable workers. The prehistoric loss of forest in the Eastern Arc Mountains was determined by comparing current to prehistoric forest cover. In estimating the latter cover, I assumed the prehistoric (earlier than approximately 2,000 years BP) lower forest boundary on the eastern or windward side of each of the Eastern Arc Mountains began at their base. On the western or leeward side of the mountains, because of the rain shadow effect, I assumed that the lower forest boundary began 400 m higher than on the eastern side. For example, in the East Usambara Mountains, I estimated the lower prehistoric forest boundary on the eastern side was 150 m a.s.l. and 550 m a.s.l. on the western side. For all of the Eastern Arc Mountains, I assumed the prehistoric forest cover was unbroken and the upper plateau regions were entirely forest covered.

Methodological constraints

The utility of aerial imagery in mapping forest area is well documented (Reeves, 1975). However, any estimate of forest area derived from aerial imagery is dependent upon how forest types are classified. The recent 1:250,000 land cover and use maps (Ministry of Natural Resources and Tourism, 1996) have used very broad categories in classifying 'natural forest'. Based upon my own inspection on the ground of several sites in the East and West Usambara and North Pare Mountains, photo-interpreters have combined 'open forest', forest in which the over-storey canopy is broken and non-contiguous, with 'closed forest', forest in which the over-storey canopy is generally intact and contiguous, in classifying vegetation as 'natural forest'. Much of what is 'open forest' is actually woodland (*e.g.* the lower elevational regions of the Pare Mountains, personal observation). Furthermore, in a few sites, photo-interpreters have mistakenly classified closed forest as cultivated lands (*e.g.* the Ambangulu Forest in the West Usambara Mountains, personal observation). In general, the current land use and cover maps over-estimate the amount of natural forest in the Eastern Arc Mountains, and thus the estimates that I present of 'natural forest' cover in the Eastern Arc Mountains are a maximum estimate of forest area. Additionally, the estimates I present of median and mean forest patch size are maximum estimates, because the 1:250,000 land use and cover maps have excluded forest patches smaller than approximately 1.5 km^2.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

While the current classification system should be adequate to assess particularly the watershed values of the Eastern Arc Mountains, it is somewhat less useful in assessing the conservation values of these mountains because species diversity and endemism tend to be concentrated in closed forest. Thus to address this potential constraint, I have included independent estimates by various workers of closed forest. I compiled estimates from the literature and interviewed knowledgeable workers of closed forest cover for all of the Eastern Arc Mountains with the exception of the Mahenge Mountains. However, it should be noted that for most of the Eastern Arc Mountains these estimates of closed forest area are based upon visual assessments in the field, and thus there is an unknown measurement error associated with these figures.

A final methodological constraint is that the topographical coverage available for the Eastern Arc Mountains is variable. In estimating the prehistoric forest boundary for the Taita Hills, East and West Usambara, North and South Pare, and the Udzungwa Mountains, I used 1:250,000 scale topographic maps. For the Uluguru, Ukaguru, Nguru, and Rubeho, and Mahenge Mountains, I used 1:500,000 scale maps. Because the elevation contours on the 1:500,000 scale maps are wider than on the 1:250,000 scale maps, I had to interpolate the location of the prehistoric forest boundary in places on the 1:500,000 scale maps. Thus the estimates of the prehistoric forest cover for Uluguru, Ukaguru, Nguru, Rubeho, and Mahenge Mountains contain probably a larger measurement error than for the Taita Hills, East and West Usambara, North and South Pare, and Udzungwa Mountains.

RESULTS

Natural forest

The maximum total area of natural forest, open as well as closed forest, in the Eastern Arc Mountains is 5,340 km^2. The Udzungwa Mountains contain the largest area of natural forest followed by the Nguru, Uluguru, Rubeho, East Usambara, South Pare, West Usambara, Mahenge, Ukaguru, North Pare Mountains, and the Taita Hills (table 1).

Patch size

The remaining natural forest in the Eastern Arc Mountains is highly fragmented. The median natural forest patch size across all of the Eastern Arc Mountains is 10.2 km^2, while the mean natural forest patch size is 58.0 km^2. The Udzungwa and West Usambara Mountains contain the largest number of forest fragments (table 1).

The frequency distribution in the size of natural forest patches for most of the Eastern Arc Mountains tends to be negatively skewed, with most mountains containing more small than large patches (figure 1).

Closed forest

Much of the current natural forest in the Eastern Arc Mountains has been extensively disturbed. Based upon estimates of various workers, the total remaining closed forest cover in the Eastern Arc forests is approximately 1,447 km^2 or 27 % of the remaining natural forest (table 1). This estimate of total closed forest cover may be conservative, because it does not include the closed forest in the Mahenge Mountain. Based upon the location and elevation of this mountain, I would predict that closed forest cover in the Mahenge Mountain is less than 50 km^2. Thus, the upper limit of closed forest cover in the Eastern Arc Mountains is probably less than 1,497 km^2.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

The Eastern Arc Mountains containing the greatest amount of closed forest are the Udzungwa and East and West Usambara Mountains (table 1).

Change in forest cover

Assuming that nearly all of the Eastern Arc Mountains were covered prehistorically by forest, 77 % of the original Eastern Arc forest has been lost due to human disturbance and fire over the last approximately 2,000 years. The greatest proportional loss of forest has occurred in the Taita Hills, Ukaguru, Mahenge, and West Usambara Mountains (table 1).

Table 1. Description of forest cover in the Eastern Arc Mountains

Eastern Arc Mountain	Natural forest (km^2)	Number of forest patches	Closed forest (km^2)	Loss of original forest cover (%)
Taita Hills	6[a]	13	4[a]	98
North Pare	151	2	28[b]	50
South Pare	333	5	120[c]	73
West Usambara	328	17	245[d]	84
East Usambara	413	8	221[e]	57
Nguru	647	8	120[f]	82
Ukaguru	184	1	100[f]	90
Uluguru	528	5	120[f]	65
Rubeho	499	6	100[g]	37
Mahenge	291	3	-[h]	89
Udzungwa	1960	26	389[i]	76

a. Source: personal communication, L. Lens.
b. Source: personal communication, N. Cordeiro.
c. Source: personal communication, W. Stanley.
d. Source: Stuart (1983).
e. Source: Hyytiäinen (1995); Johansson & Sandy (1996).
f. Source: Collar & Stuart (1988).
g. Source: Fjeldså *et al.* (1997).
h. Data unavailable. However, based upon the location and elevation of this mountain, I would predict that the total area of closed forest is less than 50 km^2.
i. Source: Rodgers & Homewood (1982); Moyer (1992).

DISCUSSION

The Eastern Arc Mountains have experienced a significant loss and fragmentation of forest over time. Although archaeological evidence indicates human presence in the Eastern Mountains Arc for at least 2,000 years (Schmidt, 1989), much of the loss and disturbance of forest has probably occurred within the last 200 years as a result of human population growth during this period. In the West Usambara Mountains, human population has increased by more than 23-fold since the turn of this century (Iversen, 1991). Based upon species-area relationships (Wilson, 1988; Reid & Miller, 1989; Simberloff, 1992; Whitmore, 1997), a loss of 77 % of the original forest in the Eastern Arc Mountains suggests that approximately 31 % of the species in the Eastern Arc Mountains have become extinct *or* are in danger of extinction. However this estimate of past as well as future species loss based upon species-area relationships is conservative for several reasons. First, the remaining forest in the

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Eastern Arc Mountains is highly fragmented and the forest patches are small. Thus a 77 % loss in forest has reduced populations on average by considerably more than 31 %

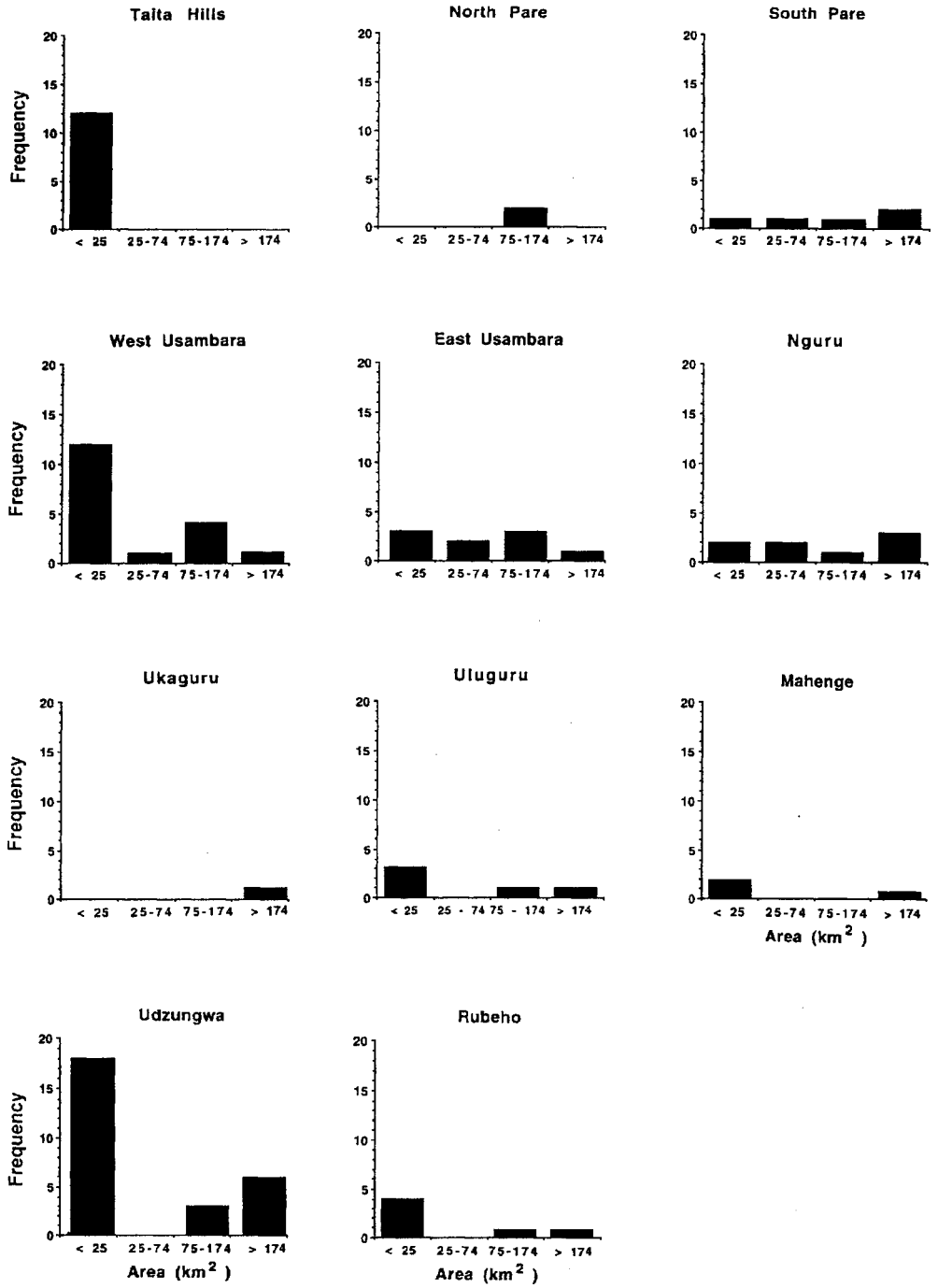


Figure 1. Frequency distribution by size classes (< 25 km^2, 25–74 km^2, 75–174 km^2, > 174 km^2) of natural forest fragments in the Eastern Arc Mountains

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

(Wilson, 1988). Secondly, many of the species occurring in the Eastern Arc forests have very restricted geographic ranges, and therefore the chance that a species will be entirely eliminated by the loss of forest increases with fragmentation. Arthropods and insects should be particularly adversely affected by forest fragmentation because of their highly restricted distributions in most tropical forests (Erwin, 1982; Didham, 1997). Thirdly, many species of insects, birds and mammals occurring in tropical forests are inhibited from crossing forest gaps (Willis, 1979; Powell & Powell, 1987; Klein, 1989; Schwarzkopf & Rylands, 1989). Based upon 12 consecutive years of studying understorey bird movement and dispersal in the East and West Usambara Mountains, I estimate that approximately one-sixth of the understorey bird species in the Eastern Arc Mountains will not cross forest gaps wider than a few hundred metres. As a result, many isolated populations will not be 'rescued' or supplemented by individuals dispersing from adjacent forest patches, and therefore these isolated populations face additional risks of extinction. And fourthly, forest fragmentation is almost always accompanied by forest degradation, over-exploitation, and the introduction of exotic species, which will yet further reduce populations.

Given the small size of the remaining forest patches in the Eastern Arc Mountains, the restricted geographic distribution of many species, and the reluctance of many taxa to cross forest gaps, it is critical that the larger forest patches in many of the Eastern Arc Mountains are reconnected with wildlife corridors in order to reduce species loss over time. The mountains where it should be most feasible to do so because of topography, land use, and distance between fragments are the East and West Usambara, Nguru, and Udzungwa Mountains. These same mountains, fortunately, also contain most of the largest remaining blocks of forest in the Eastern Arc Mountains (figure 1). Thus, the creation of wildlife corridors in the East and West Usambara, Nguru, and Udzungwa Mountains would result in the reconnection of most of the largest remaining blocks of forest in the Eastern Arc Mountains.

A comprehensive proposal has been developed to reconnect the largest blocks of forest with wildlife corridors in the East Usambara Mountains (Newmark, 1992, 1993), and implementation is proceeding (V. Pohjonen, pers. comm.). Detailed studies should be initiated in the West Usambara, Nguru, and Udzungwa Mountains to identify and design wildlife corridors to reconnect the largest blocks of forest in these mountains.

ACKNOWLEDGEMENTS

I thank Luc Lens, Norbert Cordeiro and William Stanley for data on forest cover for the Taita Hills, North and South Pare Mountains, respectively, Neil Burgess and Jon Fjeldså for their comments, and the Tanzania Commission for Science and Research for permission to conduct this work.

REFERENCES

Collar, N.J. & S.N. Stuart (1988). Key Forests for Threatened Birds in Africa. *International Council for Bird Preservation Monograph* No. **3.**

Diamond, J.M. (1984). Historic extinctions: a Rosetta stone for understanding prehistoric extinctions. In P.S. Martin & R.G. Klein, eds., *Quaternary Extinctions*. University of Arizona Press, Tucson, Arizona. Pp. 824–862.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Didham, R.K. (1997). The influence of edge effects and forest fragmentation on leaf litter invertebrates in Central Amazonia. In W.F. Laurance & R.O. Bierregaard, eds., *Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities*. The University of Chicago Press, Chicago. Pp. 55–70.

Erwin, T.L. (1982). Tropical forests: their richness in Coleoptera and other arthropod species. *Coleopterists' Bulletin* **36**: 74–75.

Fjeldså, J., K.M. Howell & M. Andersen (1997). An ornithological visit to the Rubeho Mountains, Tanzania. *Scopus* **19**: 73–82.

Hyytiäinen, K. (1995). Land use classification and mapping for the East Usambara Mountains. *East Usambara Catchment Forest Project Technical Paper* No. 12, Vantaa.

Iversen, S.T. (1991). *The Usambara Mountains, NE Tanzania: History, Vegetation and Conservation*. Uppsala Universitet, Uppsala.

Johansson, S. & R. Sandy (1996). *Selected updated land use information in the Usambara Mountains*. East Usambara Catchment Forest Project, Tanga.

Jolly, D., D. Taylor, R. Marchant, A. Hamilton, R. Bonnefille, G. Buchet & G. Riollet (1997). Vegetation dynamics in central Africa since 18,000 yr BP: pollen records from the interlacustrine highlands of Burundi, Rwanda, and western Uganda. *Journal of Biogeography* **24**: 495–512.

Klein, B.C. (1989). Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. *Ecology* **70**: 1715–1725.

Moyer, D.C. (1992). Report on the natural resource consultancy for the Udzungwa forest management project. Danish International Development Agency, Dar es Salaam.

Newmark, W.D. (1992). Recommendations for wildlife corridors and the extension and management of Forest Reserves in the East Usambara Mountains, Tanzania. *East Usambara Catchment Forest Project Technical Paper* No. 4. Helsinki.

Newmark, W.D. (1993). The role and design of wildlife corridors with examples from Tanzania. *Ambio* **22**: 500–504.

Powell, A.H. & G.V.N. Powell (1987). Population dynamics of male euglossine bees in Amazonian forest fragments. *Biotropica* **19**: 176–179.

Reeves, R.G. (ed.) (1975). *Manual of Remote Sensing*. American Society of Photogrammetry, Falls Church, Virginia.

Reid, W.V. & K.R. Miller (1989). *Keeping Options Alive: The Scientific Basis for Conserving Biodiversity*. World Resource Institute, Washington D.C.

Rodgers, W.A. & K.M. Homewood (1982). Biological values and conservation prospects for the forests and primate populations of the Uzungwa Mountains, Tanzania. *Biological Conservation* **24**: 285–304.

Schmidt, P.R. (1989). Early exploitation and settlement in the Usambara Mountains. In A.C. Hamilton & R. Bensted-Smith, eds., *Forest Conservation in the East Usambara Mountains, Tanzania*. IUCN, Gland and Cambridge. Pp. 75–78.

Schwarzkopf, L. & A.B. Rylands (1989). Primate species richness in relation to habitat structure in Amazonian rainforest fragments. *Biological Conservation* **48**: 1–12.

Simberloff, D. (1992). Do species-area curves predict extinction in fragmented forest? In T.C. Whitmore & J.A. Sayer, eds., *Tropical Deforestation and Species Extinction*. Chapman and Hall, London. Pp. 75–86.

Stuart, S.N. (1983). Biogeographical and ecological aspects of forest bird communities in eastern Tanzania. PhD dissertation. Cambridge University, Cambridge.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use

Whitmore, T.C. (1997). Tropical forest disturbance, disappearance and species loss. In W.F. Laurance & R.O. Bierregaard, eds., *Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities*. The University of Chicago Press, Chicago. Pp. 3–12.

Willis, E.O. (1979). The composition of avian communities in luminescent woodlots in southern Brazil. *Papéis Avulsos de Zoologia, Sao Paulo* **33**: 1–25.

Wilson, E.O. (1988). The current state of biological diversity. In E.O. Wilson ed., *Biodiversity*. National Academy Press, Washington D.C. Pp. 3–18.

Downloaded From: https://bioone.org/journals/Journal-of-East-African-Natural-History on 28 Mar 2024
Terms of Use: https://bioone.org/terms-of-use