Fifteen Years of Community-Based Monitoring of Mammals and Birds in Forest Stewardship Council Certified Forest Areas in Tanzania

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Key Points:

1. Tanzanian community-elected committees of villagers can generate useful biodiversity data over long periods within a community-led certification framework.
2. Threatened mammals and birds persists in community-managed forests despite more than a decade of selective logging activity by the communities.
3. Our results suggest community-managed forests function as independent conservation habitats with no significant influence from protected areas.

Key words:

Community-based monitoring, Mpingo Conservation & Development Initiative, forest certification, East Africa

Abstract:

Certified community-managed forests are rare in East Africa, and the use of community-based monitoring to track biodiversity change in such forests is rarer still. We analyse 15 years of community-collected data on the status and abundance of mammals and birds from 10 village land forest reserves in southern coastal Tanzania, managed under a Forest Stewardship Council certification scheme facilitated by Mpingo Conservation & Development Initiative. Using standardised encounter rates from regular patrol data, we assess biodiversity trends, compare detection between harvest and no-take zones, and examine the relationship between encounter rates and proximity to protected areas. Globally threatened mammal and bird species were recorded consistently throughout the monitoring period, with limited evidence of change in biodiversity importance over the period of logging activity. Encounter rates did not differ significantly between harvest and no-take zones and showed no clear relationship with distance to protected areas, suggesting the community-managed forests function as important habitats for mammals and birds. Our findings demonstrate that community-elected committees of forest users in Tanzania can generate highly valuable biodiversity data to inform community decision-making over sustained periods within a formal certification framework. Recommendations are made for further improvements to data collection and data management to strengthen the community-based monitoring program going forward.

Plain Language Summary:

If communities are to benefit economically from selling certified sustainably harvested timber from community-managed forests to local, national and international markets, they must demonstrate that the biodiversity in their timber production areas is preserved. This requires monitoring of the forest flora and fauna. However, the results of community-based forest biodiversity monitoring programs are rarely explored, because they have not yet generated sufficient data for analysis. In southern coastal Tanzania, the local non-governmental organization Mpingo Conservation & Development Initiative (MCDI) have facilitated that 10 villages have tracked the status and abundance of mammals and birds in their timber production areas since 2009. We find that the community-managed forests provide important, independent habitats where threatened mammals and birds continue to persist despite years of sustainable selective logging, and that the villagers engaged in the timber certification framework can generate useful biodiversity data. Based on this work, we offer a set of recommendations for further enhancing the community-based monitoring program. MCDI's approach shows how community-based biodiversity monitoring by rural, forest-dependent communities can be integrated into sustainable forest governance.

1 Introduction

1.1 Tanzania’s biodiversity and conservation pressures

Tanzania is recognized for its considerable biodiversity and ecological significance, home to 242 endemic vertebrates and at least 553 endemic plant taxa (Meng et al., 2016; Ract et al., 2024), and contains six out of the 36 globally designated biodiversity hotspots (conservation.org, 2025; Sheik & Cook, 2024). The coastal forests of Tanzania, part of the Coastal Forests of Eastern Africa biodiversity hotspot – are one of the highest priority global conservation areas (Mittermeier et al., 2004). Woodlands cover a significant part of the country as seen in Figure 1*a*, supporting large mammal populations and millions of people through forest products and ecosystem services (Abdallah & Monela, 2007).

In recent decades competition for land resources from a growing population, has led to significant pressures on biodiversity, with agricultural expansion, overgrazing, unsustainable resource exploitation, bushfires, and charcoal production as key drivers (Sheik & Cook, 2024). As a result, coastal forests and miombo woodlands have shrunk in size, with particular losses outside protected and conserved areas (Burgess et al., 2017).

1.2 Community-based forest management in Tanzania

An important response to these pressures has been the development of Community-Based Forest Management (CBFM). In the early 1990’s, Tanzania was among the first countries in Africa to recognize the role of local communities in forest conservation, as state-governed forests faced increasing degradation from poorly regulated use. This shift, facilitated by the 1998

National Forest Policy and the Forest Act No. 14 of 2002, marked a turning point in Tanzanian forest policy (Blomley & Iddi, 2009; FBD, 2022; URT, 2007). CBFM has been supported by the Tanzanian government and international development agencies, with NGOs and Local Authorities as primary drivers of implementation (Katani & Kajembe, 2019).

In Tanzania, CBFM gives communities management responsibilities and ownership, empowering them to protect the designated areas for traditional purposes and conduct forest restoration and sustainable harvesting activities (FBD, 2007). CBFM-managed forests have shown low rates of forest loss, good management effectiveness, an increased number of stems per hectare and better forest conditions compared to open forest lands and government reserves (Blomley & Iddi, 2009; Katani & Kajembe, 2019). This decentralised forest management has also delivered tangible benefits for people, including household improvements for participants and contributions to social services, school facilities, and development projects (Bennett et al., 2018; MCDI, 2024).

1.3 The role of communities in forest monitoring

Community-based monitoring has proven a cost-effective tool that can enhance the capacity of local communities, deliver data quality comparable to that of professional scientists, and support appropriate management interventions at the local scale (Benyei et al., 2023; Danielsen et al., 2021; Dawson et al., 2021; Porter-Bolland et al., 2012). Understanding the theoretical basis for this effectiveness draws on the framework of environmental stewardship (Danielsen et al., 2021; Pierce and Jussila, 2010), which recognises that responsibility and ownership function as motivators for individuals to act in collective interests, fostering commitment to conservation outcomes. For this stewardship to succeed the necessary cultural, social, institutional, and financial capabilities must be present and supported by governance institutions (Bennett et al., 2018; Pierce & Jussila, 2010).

In practice, this theoretical foundation is operationalised through Participatory Forest Management frameworks, such as CBFM implemented by Tanzania, where Village Natural Resource Committees (VNRCs), a committee elected by villagers to manage the village land forest reserves (VLFRs), are granted management responsibilities and ownership over designated forest areas (FBD, 2007). By placing monitoring responsibility with VNRCs, local communities become integrated into national forest policy as ‘citizen scientists’, contributing data for local and national conservation initiatives through ‘Collaborative Monitoring with Local Data Interpretation’ (*sensu* (Danielsen et al., 2021). The results of such programs are rarely explored, often because they have not yet generated sufficient data for analysis (Blomley et al., 2008; Yanda et al., 2025).

1.4 Forest certification and locally managed timber harvesting

Forest certification schemes have been developed globally to support and enhance the protection and sustainability of forest practices. FSC certification was developed in 1993 and is now in operation across more than 2 million hectares of FSC-certified forests globally (FSC, 2025; Mathias et al., 2023).

FSC operates through a voluntary, market-based and multistakeholder approach involving a third-party auditing. It emphasizes equality between economy, environment and community- and indigenous rights values, by supporting zero deforestation, protection of endangered forests, fair wages, biodiversity preservation, and safeguarding of community rights (FSC, 2023, 2025).

Monitoring the FSC outcomes is necessary to assess effectiveness. While FSC-certification has been shown to reduce the environmental impacts on biodiversity, most studies have focused on flora, leaving a gap in understanding its effect on animal biodiversity in production forests (Kalonga et al., 2015; Mathias et al., 2023; Trolliet et al., 2019).

Tanzanian CBFM implementation, and associated FSC-certification for community timber production offer a promising, sustainable and cost-effective approach to local development, that simultaneously values the rights of participating communities. In practice however, engaging rural and marginalised communities as community scientists present distinct challenges, including limited technological infrastructure, unbalanced knowledge hierarchies, and questions of data rights (Benyei et al., 2023). Understanding how community-collected data performs under these conditions is therefore essential both for evaluating FSC outcomes and for advancing the theory and practice of community science in the Global South.

1.5 Aim of study

For 15 years villagers in Kilwa and Rufiji districts in Tanzania have collected data on mammals and birds in the coastal forests and miombo woodlands that are managed by their villages, but interpretation and analysis of the data have been limited. As they had invested a significant amount of time collecting the data, the communities themselves also expressed a strong interest in seeing the results of their monitoring and of forest management efforts on local biodiversity. In this paper we analyse the community-collected observations of mammals, and three bird species selected as indicators of ecosystem health. Through this analysis we aim to: 1) explore the potential of these data to detect changes in species occurrence and abundance over time;

2) evaluate how the data can be used to assess the effectiveness of sustainability practices in Forest Stewardship Council (FSC)-certified areas, and 3) assess the influence of harvest and no-take zones and proximity to state-managed protected areas on species detection.

2 Study Site

2.1 Forest types and ecology

The study sites fall within two Tanzanian districts in two regions: Kilwa district, Lindi region and Rufiji District, Pwani region (see Supplemental file: Appendix 1 for full location table). Two primary forest types are present at the project location as seen in Figure 1*b*; miombo woodlands and coastal forests, both under the influence of two rainy seasons: “short rains” (lighter rains) during November - January and “long rains” (heavier rains) during March – May.

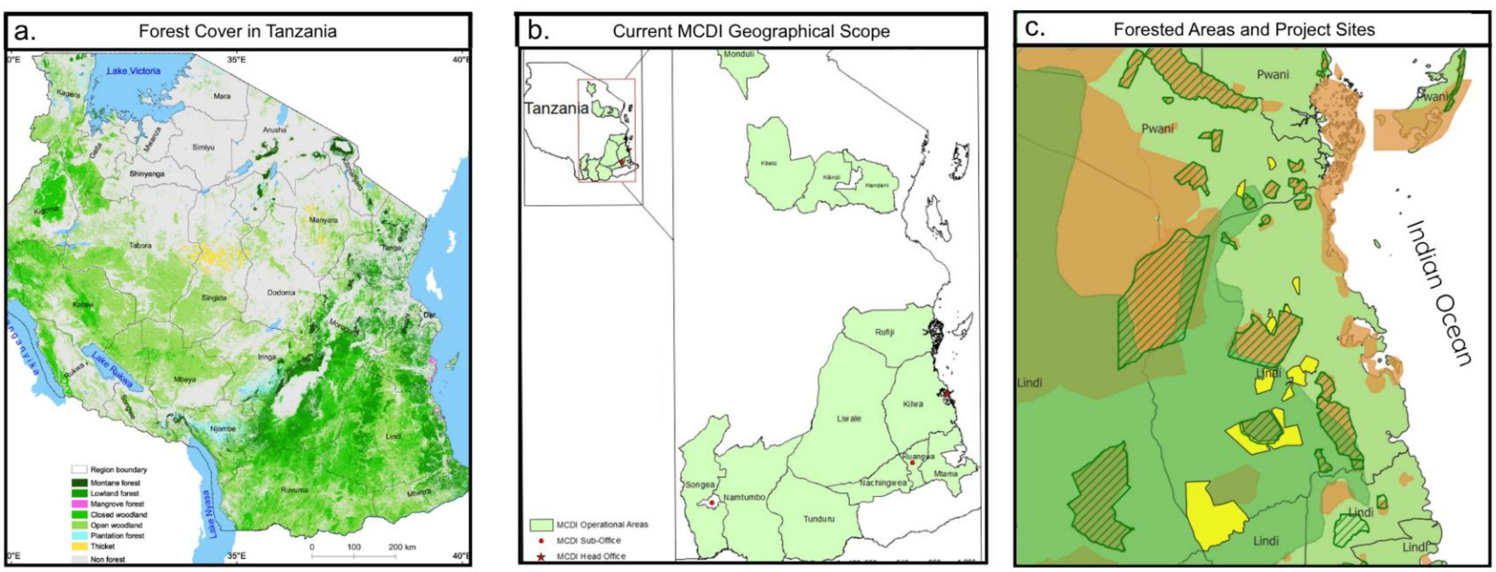

Figure 1: Location of the study area and monitoring site in Tanzania. (a) shows national forest cover (TFS, 2025); (b) shows the geographical distribution of MCDI project sites (adapted from MCDI, 2024); (c) shows the primary forest types: miombo woodlands (shaded green), coastal forests (hatched), protected areas (brown), and FSC-certified VLFRs (yellow).

Coastal forests: Found along the coast of East Africa. Characterized by a mosaic of thickets, lowland forest patches, and bushlands with average temperatures above 25℃ and mean annual rainfall of 1200-1500 mm. The coastal forests of Tanzania support 325 endemic vascular plant taxa, as well as notable levels of endemism across fauna: 5 endemic and 22 near-endemic bird species, 6 endemic and 3 near-endemic amphibian species, 3 endemic and 13 near-endemic reptilian species, and 5 endemic and 14 near-endemic mammals (Burgess et al., 2017). The habitat also supports several IUCN red list species, including the globally endangered species, African elephant and wild dog, the vulnerable African lion and the near threatened leopard. Coastal Forest biodiversity remains under pressure from agriculture and over-harvesting (Burgess et al., 2017; Martin & Burgess, 2020).

Miombo Woodlands: An extensive forest ecosystem found across large parts of Eastern and Southern Africa, dominated by tree species within the subfamily Caesalpinioideae. High seasonality, temperatures between 18-30℃ and average annual rainfall of 600-1000 mm, result in seasonal loss of canopy tree leaves, while understorey grass dries out and frequently burns. Miombo has low rates of endemism, with many plant and mammal species being wide ranging. Human population is low due to nutrient-poor soils, yet the exploitation of timber and conversion of forest to farmland outside of protected areas remains prevalent (Abdallah & Monela, 2007; Martin & Burgess, 2020b).

2.2 Institutional setting for community-based monitoring

Mpingo Conservation and Development Initiative (MCDI), a local Non-Government Organization, was founded in 1995 with a permanent base in Kilwa Masoko, Kilwa District, Lindi region, Tanzania (MCDI, 2024). Since 1995 MCDI has supported approximately 85 communities in coastal Tanzania (Fig. 1*b*), with the objective of utilising mpingo (*Dalbergia melanoxylon*) and other hardwood trees for revenue-generating activities through community-based conservation programs. The goal has been to make these operations self-sustaining from the income generated by their logging revenue, while fostering a relationship between communities and biodiversity conservation by providing an economic alternative to forest conversion for agriculture.

10 villages across two districts have been FSC-certified under MCDI's group certification since initial implementation in 2009, covering an area of approximately 125,847 ha. The certification aims to enhance the value of timber with 15 timber tree species sold at local, national, and international markets with the assistance of MCDI (MCDI, 2024).

In accordance with FSC requirements outlined in principle 9: High Conservation Values, including criteria 9.1 and 9.4 (FSC, 2023), the VNRCs have conducted regular monitoring of biodiversity in their forest. The certification further requires that CBFM villages declare at least 10% of their certified VLFR as a no-take conservation zone.

2.3 Community Description

The villages all comprise rural forest dependent communities who participate in FSC-certified timber harvesting and community-based forest management, where additional revenue generated through logging is enabling investment in local infrastructure and services. This has for example included construction of a local health post and school buildings, in addition to facilities such as a portable sawmill, oil pressing machinery and a hut for mushroom farming. In several of the villages, women's groups have organised small-scale income-generating activities based on non-timber forest products, including for example the local production of sunflower and sesame oil using their self-developed equipment, alongside the sale of baobab seeds.

3 Methods

3.1 Study Design

We use a non-experimental mixed-methods approach that combines qualitative and quantitative techniques, to assess the datasets gathered by the villagers in the VNRCs, forming the foundation for our evaluation of the sustainability practices in place at the community-led FSC-certified areas.

3.2 Biodiversity monitoring and data collection

After initial training and support by MCDI, biodiversity monitoring has been conducted by the VNRCs from 14 villages across 15 locations through regular patrols in their respective VLFR. However, five locations were excluded from the analysis due to insufficient data, leaving 10 locations for further analysis (see section 3.5 and Supplementary file: Appendix 3). The villages are: Mchakama, Kikole, Kisangi, Nainokwe, Liwiti, Nanjirinji A, Likawage, Ngea, Nyamwage and Tawi. The number of villages participating in the monitoring varies over time, as does the duration of their monitoring, as illustrated in Figure 2 (see Supplementary file: Appendix 1 for an overview of included and excluded villages).

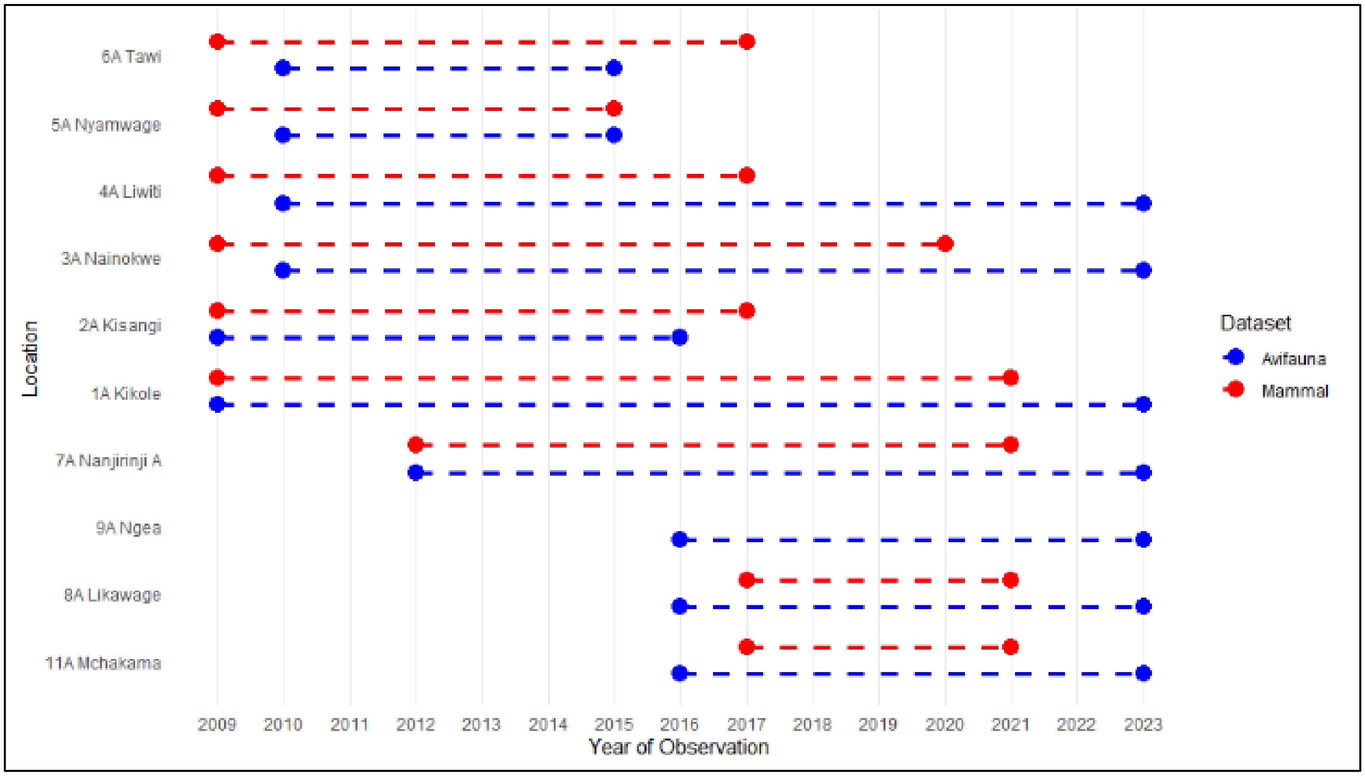

Figure 2: Timeline showing the first and last year of reported mammal (red) and bird data (blue) for each village, spanning the period 2009–2023.

From 2009, patrols took place along ad-hoc routes in different parts of the forest identified by the VNRCs, until two fixed transect lines were established at all locations in 2018 according to FSC-protocols, each 3 km long - one located in a harvest zone and the other in a no-take zone. During each patrol, all mammal encounters were noted, and for every 300 meters, the team would stop for 5 minutes and record any sightings of the indicator species. The three indicator bird species are African Broadbill (AB) – *Smithornis capensis*, Crested Guineafowl (CG) – *Guttera pucherani,* and Dark-backed Weaver (DBW) – *Ploceus bicolor*. These were selected by MCDI in dialogue with the participants in 2008 as indicators of healthy coastal forest ecosystems, based on their specific habitat and ecological requirements, as well as their ease of observation and identification by non-professionals (MCDI, 2017).

All observations were recorded with pen and paper on a form provided by MCDI and then transferred to a spreadsheet stored in an online database by MCDI employees. Two Excel datasets (*Avifauna*- and *Mammal Monitoring*) available late 2024, maintained by MCDI contain the data collected by the 10 FSC-certified villages over a 15-year period from 2009 to 2023 (see Supplemental file: Appendix 2 for species list and Appendix 3 for further details of the excel datasets). The cleaned mammal dataset contains 1,791 encounters recorded over 521 patrols, covering 29 different mammal taxa, as not all observations were recorded to species level in the field. The cleaned avifauna dataset contains 3,061 encounters across 508 patrols, limited to the three indicator species.

3.3 Mapping in GIS

To establish an overview of the geographical distribution of the locations involved in data collecting, a map, Figure 1*c* (yellow areas), was created using the QGIS 3.38.3 software. Vector shapefiles for all locations were provided by MCDI and added to a vector map over Tanzania. Additionally, a layer with polygons over protected areas (brown) and the two dominant forest types in Kilwa district was added (UNEP, 2025). All spatial layers were projected in EPSG:4326 (WSG 84) to ensure consistency and compatibility across datasets. Additionally, to account for potential spill-over effects from adjacent protected areas on wildlife encounter rates, distances from individual VLFRs to the nearest protected area and Nyerere National Park were measured using the “Measure Line” feature in QGIS.

3.4 Data organization

The first three authors discussed data analysis and organized the data with key MCDI staff and participants in the villages Liwiti and Mchakama and in the MCDI main office in Kilwa Masoko during October and November 2024. MCDI co-authors have undertaken field visits to the villages and forests studied here on numerous occasions over approximately 15 years, and NDB has visited on two occasions. MCDI has since initial project implementation, supported the participants in data collection through workshops, on-site training activities, and participation in village meetings.

3.5 Analytical Methods

Initial data preprocessing was conducted in Excel to assess quality and reliability prior to analysis (see Supplementary file: Appendix 3, for additional information). Both datasets were cleaned by correcting entry errors (e.g. misplaced values), aligning capitalisation, formatting, and replacing missing or unverifiable entries with “NA”.

The cleaned data were imported into RStudio and analysed using the packages tidyverse, broom, FSA, viridis, and patchwork. Generative AI was used to support coding and troubleshooting in RStudio, with assistance of ChatGPT (GPT-4o) and Rao by Lotas (0.4.4); all outputs were reviewed and validated by the authors. To account for uneven sampling, data were standardised by patrol effort, grouping entries by date and location.

Locations with ≤2 years of monitoring (n=5) were excluded, as were years with fewer than 10 patrols (*Mammals*: 2016, 2018; and *Avifauna*: 2009, 2017*)*. For the remaining data, encounter rates were standardised using mean encounters per patrol, calculated per taxon, location, and year, then averaged across locations within each year, controlling for patrol effort variation and enabling comparisons across locations and time periods.

The following analyses were undertaken:

A linear regression was fitted to assess the relationship between encounter rates and patrol effort for each aggregated dataset. Seasonal differences in encounter rates were visualized using violin plots.

Local population trends were calculated as mean encounter rates per patrol for each taxon and presented alongside IUCN global population trends for comparison. Taxa observed in fewer than 2 monitoring years (n=5) were excluded from individual trend analysis, as it was not feasible to calculate a population trend.

A temporal line chart was used to show mean encounters per patrol within each IUCN threat category across the monitoring period, illustrating changes in the composition of Red List species encounters over time.

Detection frequency was calculated as the percentage of total patrols on which each taxon was recorded across all locations, with total encounter count noted alongside. Where possible, taxa were classified by IUCN Red List status to contextualise detection patterns relative to conservation concern.

Box plots and a Kruskal-Wallis test were used to assess whether standardised encounter rates differed significantly between the harvest and no-take zones, using data from 2018 onwards when the zones were established, to evaluate whether zone designation under the FSC-certification protocol influenced wildlife detection.

Lastly, scatter plots and Spearman's rank correlations tests were used to examine the relationship between encounter rates and distance to the nearest protected area and Nyerere National Park.

4 Results

4.1 Encounter rates increased over time with no significant seasonal variation

Encounter rates for both mammals and avifauna suggest a general increase over time as demonstrated in Figure 3. Patrol effort varied across years, with the largest spike for *Mammals* around 2017 (mean ~20 patrols) and for *Avifauna* around 2014 (mean ~12 patrols). A weak but significant negative relationship between patrol effort and encounter rate was found for *Avifauna* (slope = -1,06, $p < 0.041$) but not for mammals (slope = -0.09, $p = 0.41$), suggesting that avifauna encounter rates may be partially influenced by sampling intensity.

Encounter rates did not differ significantly across seasons for either dataset (Kruskal-Wallis: *Mammals* χ^2=2.65 $p = 0.26$, *Avifauna* χ^2=0.97 $p = 0.61$), as demonstrated by the violin plots in Figure 3, with broadly comparable sample sizes across seasons (*Mammals*: 118–233 patrols; *Avifauna*: 112–222 patrols).

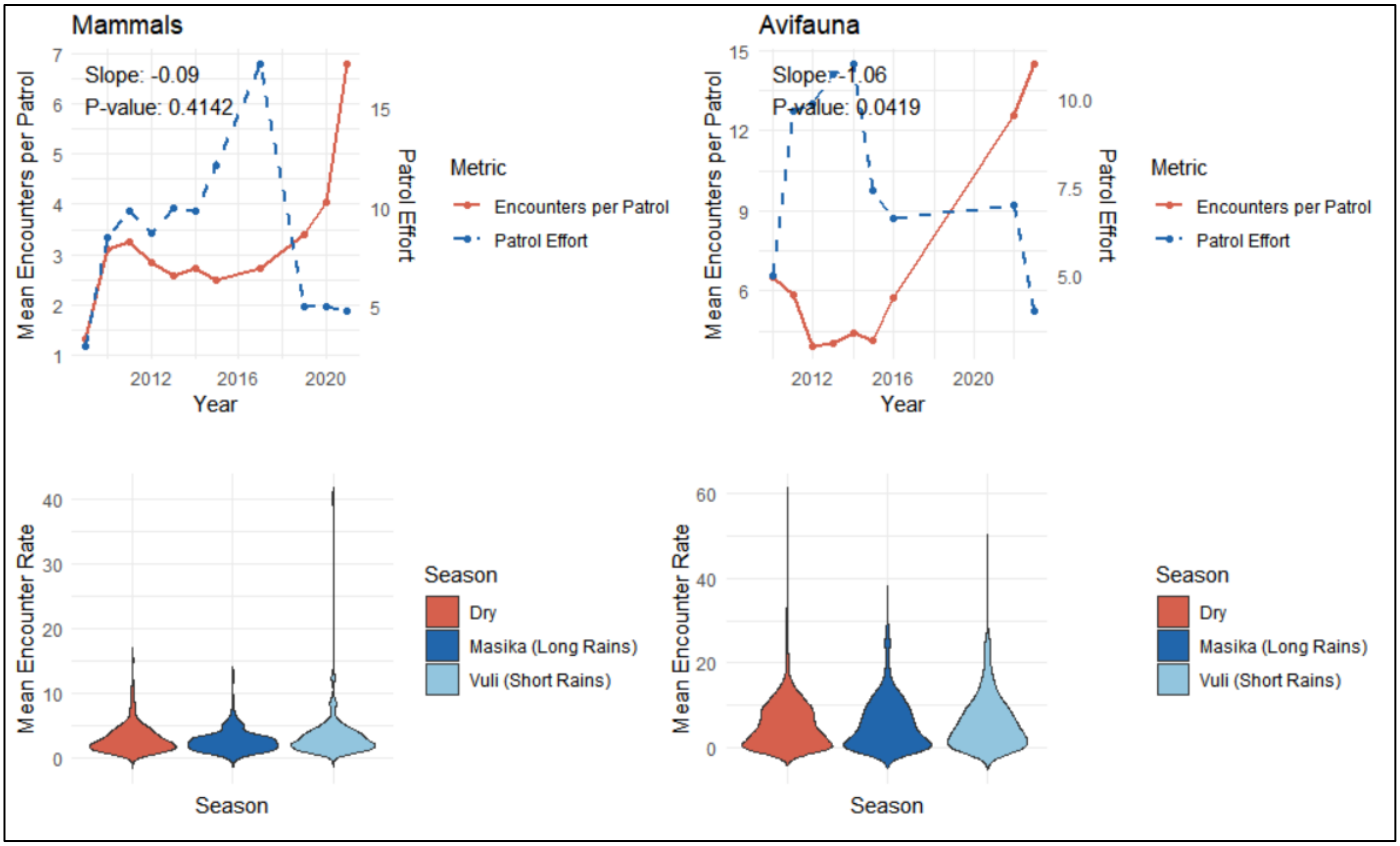

Figure 3:Top: Linear regression of encounter rate against patrol effort across years for mammals (2009-2021) and avifauna (2010-2023). Bottom: Violin plots illustrating the distribution of encounter rates across seasons for both datasets.

4.2 Local monitoring reveals divergent trends for select species relative to global assessments

A few mammal species had significant local observation trends ($R^2 \geq 0.5$; Table 1). Wild dogs, recorded between 2019-2021, showed a positive trend (slope = 9.5, $R^2 = 0.828$), contrary to the species' global population decline, although this should be interpreted cautiously given the three-year observation window. Waterbuck, recorded between 2010 and 2017, showed a declining local trend (slope = -0.374, $R^2 = 0.524$), contrary to its globally stable status. Bush baby showed a positive trend (slope = 2, $R^2 = 0.952$), but as the species identification was unconfirmed, no global comparison could be made.

For *Avifauna*, African broadbill and crested guineafowl both showed increasing local trends (slopes ~4.5; R^2 = 0.511 and 0.604 respectively), contrary to the globally decreasing trend for African broadbill and globally stable trend for crested guineafowl.

Table 1: Local and global population trends for monitored taxa. Local trends are based on linear regression of encounter rates over time; taxa with $R^2 > 0.50$ has been marked with bold font. Global trend is based on IUCN 2025 (IUCN, 2025). EN, endangered, VU, vulnerable, NT, near threatened, LC, Least Concern.

Common name	Scientific name	Mean N encounter/year	Years observed (N)	IUCN Red List	Local Trend	R^2	Global Trend
Mammals							
Elephant	*Loxodonta africana*	38.63	2009-2021 (11)	EN		0.004	Decreasing
Baboon	*Papio anubis*	22.90	2010-2021 (10)	LC		0.067	Stable
Dik dik	*Madoqua kirkii*	20.00	2010-2017 (7)	LC		0.014	Stable
Buffalo	*Syncerus caffer*	14.11	2010-2021 (9)	NT		0.062	Decreasing
Warthog	*Phacochoerus africanus*	12	2010-2021 (10)	LC		0.013	Decreasing
Wild pig	NA	10.12	2010-2021 (8)	NA		0.007	NA
Wild dog	*Lycaon pictus*	9	2019-2021 (3)	EN	9.500	**0.828**	Decreasing
Bushbuck	*Tragelaphus scriptus*	8.83	2011-2017 (6)	LC		0.149	Stable
Hartebeest	*Alcelaphus lichtensteinii*	7.90	2010-2021 (10)	LC		0.122	Decreasing
Elephant shrew	*Petrodromus tetradactylus*	7.83	2009-2021 (10)	LC		0.073	NA
Zebra	*Equus quagga*	6.70	2010-2021 (10)	NT		0.109	Decreasing
Eland	*Tragelaphus oryx*	6.55	2009-2019 (9)	LC		0.136	Stable
Hyaena	*Crocuta crocuta*	5.85	2011-2020 (7)	LC		0.053	Decreasing
Duiker	NA	5.42	2010-2017 (7)	NA		0.183	NA
Blue monkey	*Cercopithecus mitis*	4.66	2011-2017 (6)	LC		0.001	Decreasing
Bush baby	NA	4.50	2011-2014 (4)	NA	2	**0.952**	NA
Sable antelope	*Hippotragus niger*	4.44	2010-2021 (9)	LC		0.006	Stable

Leopard	*Panthera pardus*	4	2010-2020 (6)	VU		0.223	Decreasing
Lion	*Panthera leo*	3.60	2010-2021 (10)	VU		0.026	Decreasing
Gazelle	NA	3.28	2009-2021 (7)	NA		0.097	NA
Waterbuck	*Kobus ellipsiprymnus*	3.25	2010-2017 (4)	LC	-0.374	**0.524**	Decreasing
Hippopotamus	*Hippopotamus amphibius*	3	2011-2021 (9)	VU		0.061	Stable
Porcupine	*Hystrix cristata*	3	2010-2015 (4)	LC		0.449	NA
Rabbit/hare	NA	2.28	2011-2021 (7)	NA		0.298	NA
Avifauna							
African broadbill	*Smithornis capensis*	122	2010-2023 (9)	LC	4.417	**0.511**	Decreasing
Dark-backed weaver	*Ploceus bicolor*	111.44	2010-2023 (9)	LC		0.279	Stable
Crested Guineafowl	*Guttera pucherani*	96.88	2010-2023 (9)	LC	4.530	**0.604**	Stable

4.3 IUCN Red List species recorded span four categories, with variable encounter rates and weak but significant increases in Endangered and Near Threatened species

In the FSC-certified areas, species from four IUCN categories were recorded: Endangered (2), Vulnerable (3), Near Threatened (2) and Least Concern (15), while the remaining seven recorded taxa were omitted from status-specific evaluations, as they either lacked global IUCN classifications or could not be identified to species level (see Supplemental file: Appendix 1 for a full list of recorded taxa and IUCN categories).

Least Concern species accounted for the highest average encounter rate with 1.33 encounters per patrol, followed by Endangered (1.07), Near Threatened (0.54) and Vulnerable species (0.3).

In terms of temporal trends across IUCN categories in Figure 4, statistically significant increasing trends were found for Endangered (slope=0.1 and p=0.007, R^2 =0.13) and Near Threatened species (slope of 0.16 p=0.007, R^2 0.17). However, the weak fit in both cases indicates that temporal trends account for only a small proportion of the variation in encounter rates.

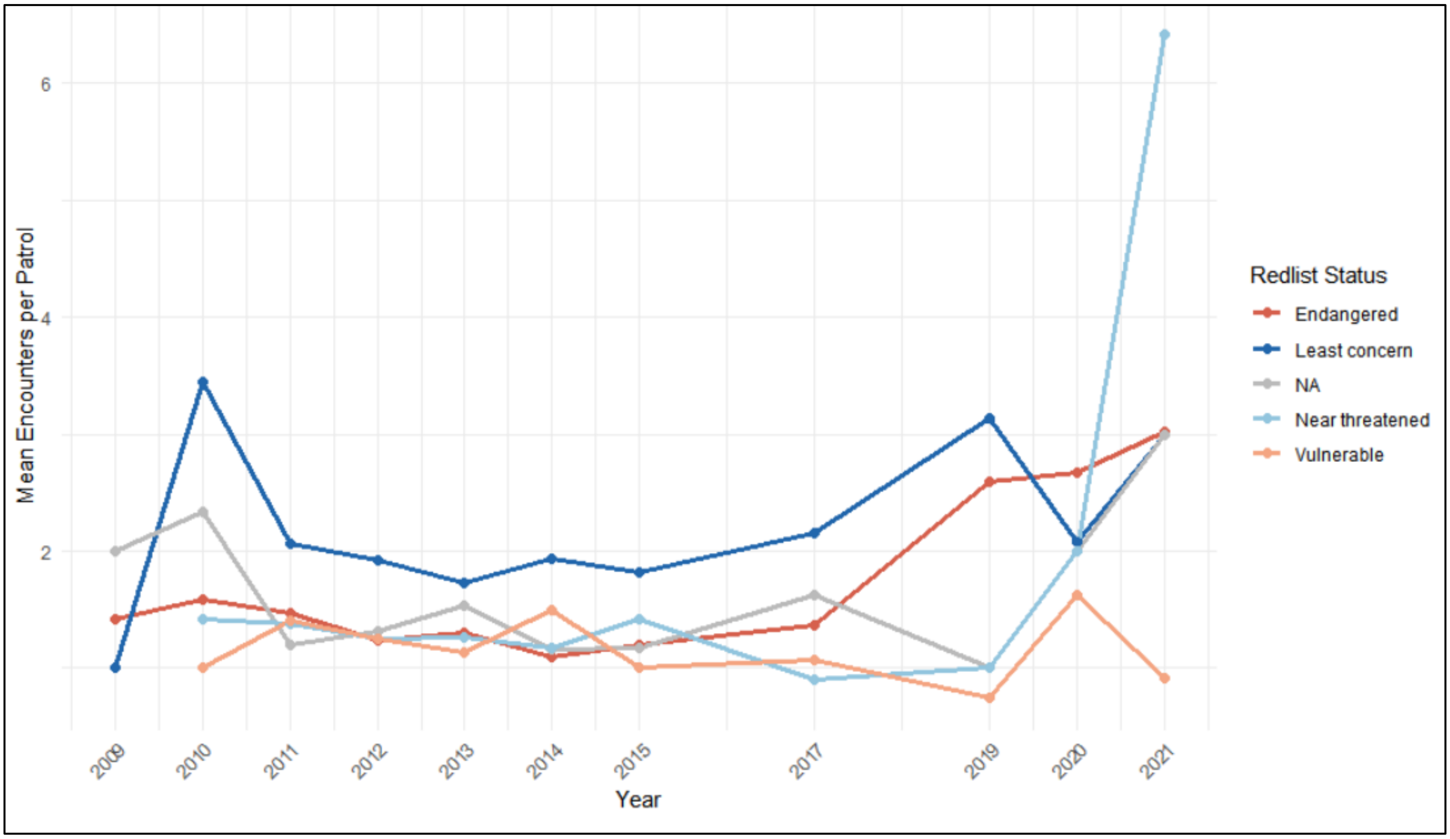

Figure 4: Temporal trend in mean encounters per patrol across IUCN Red List categories for mammal species, spanning the period 2009-2021. N/A indicates taxa that were not identified to species level or for which IUCN status information was unknown.

Detection frequency varied considerably across taxa as demonstrated in Figure 5. The endangered elephant had the highest detection rate, recorded in over 40% of patrols, with 425 total encounters, compared to the only other endangered species encountered, wild dog, which was detected in fewer than 5% of patrols with 27 encounters. Most taxa (23 of 29) were recorded in fewer than 10% of the patrols, with 6 taxa exceeding this threshold.

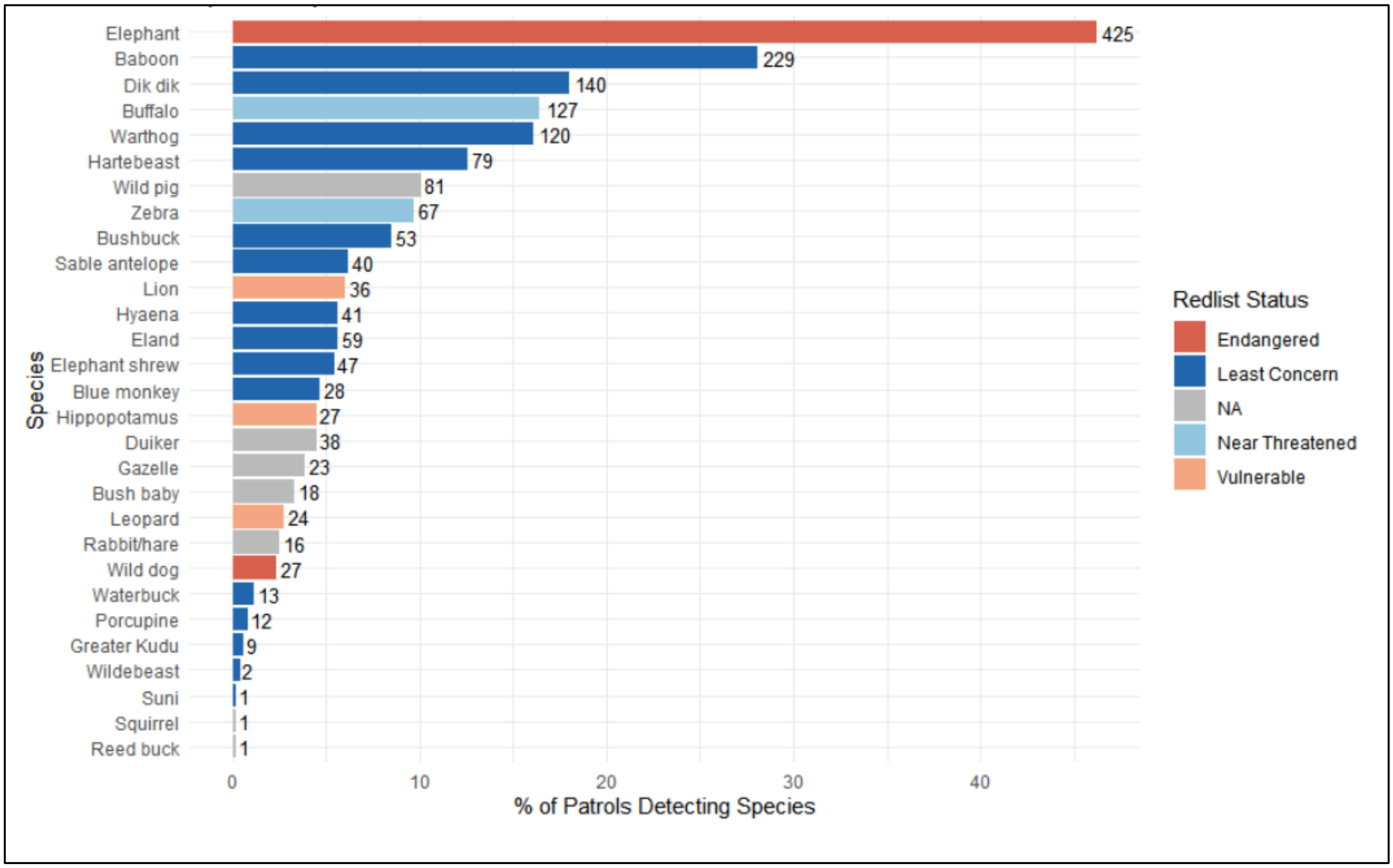

Figure 5: Percentage of patrols detecting each mammal taxa across the monitoring period, with total encounter counts labelled. Taxa are coloured by IUCN Red List Status. NA indicates taxa that could not be identified to species level or for which IUCN status information was unknown or unclassified.

4.4 No significant difference in encounter rates between harvest and no-take zones

Kruskal-Wallis tests revealed no significant differences in standardised encounter rates between harvest and no-take zones for either *Mammals* ($\chi^2 = 0.04$, df = 1, p = 0.85) or *Avifauna* ($\chi^2 = 0.28$, df = 1, p = 0.60). For M*ammals*, median encounter rates were 3 (IQR 3.25) in harvest zones and 2.5 (IQR 5.25) in no-take zones, with the considerable variability in no-take zone records likely contributing to the non-significant result. *Avifauna* median encounter rates were 3 in both zones with IQR 6 and IQR 7 in harvest zone and no-take zones respectively.

4.5 Encounter rates show no significant relationship with proximity to protected areas

Spearman's rank correlation tests found no significant relationship between mean encounters per patrol and distance to the nearest protected area for either *Mammals* (rho = 0.39, p = 0.29) or *Avifauna* (rho = 0.12, p = 0.7). Similarly, no significant relationship was found between encounter rates and distance to Nyerere National Park for mammals (rho = -0.26, p = 0.49) or avifauna (rho = 0.45, p = 0.19).

5 Community impact

Field visits and semi-structured interviews with Chief Executive Officer Jasper Makala and MCDI Field Officer Mussa Shija provided insight into the impact that the project has had at the community level. The community-based monitoring program facilitated by MCDI enables the communities to generate greater revenue from their forests, with approximately 75% of village income derived from selling timber and non-timber forest products. The income from timber sales is normally distributed with 45% to village forest management, 50% to village development and 5% for the district committee. The added revenue generated from selling sustainable forest products has reduced MCDI and the villages' reliance on external funding and enabled continuous small-scale infrastructure developments in the villages involved.

Project engagement, via forest patrols and workshops has resulted in community members reporting increased awareness and knowledge of the economic value and resources present in their forests and thus, enabled greater overall confidence from their growing financial independence (J. Makala, personal communication, November 2024).

For some of the community members this sense of agency has extended to their establishment of new community-driven conservation initiatives such as self-funded purchases of GPS equipment to improve monitoring and the initiation of enrichment planting (M. Shija, personal communication, October 2024)

The community members that have participated in the monitoring activities, have collected large datasets on mammals and birds that, as demonstrated in this study, can inform biodiversity status and trend analysis at the local level, advancing scientific understanding of Tanzania's miombo woodlands and coastal forests.

6 Discussion

In this paper we have used community collected data on mammals and birds from village lands forest reserves under logging or non-logging regimes to understand how biodiversity values have changed over time. Our results are informative on the benefits of this kind of monitoring and raise a number of issues for discussion.

6.1 What do the results tell us?

Our examination of the community-collected data reveals encouraging results about the condition of these forests, which have been managed by the communities through selective logging, and which have also been subject to other pressures such as poaching of elephants for ivory and hunting for bushmeat. Despite these pressures, and perhaps due to the community interest and benefits from the logging activities, the monitoring has shown continued presence of mammals – including those regarded as globally threatened by extinction, and bird species that indicate healthy coastal forest habitats.

The community-based monitoring started from donor funding with NGO facilitation but has evolved into a largely self-sustained program in villages benefitting from logging activities. That the data had not been fully analysed prior to this study suggests further capacity is required to analyse population changes and detect change in the abundance of key species related to FSC-certified logging or external threats. The absence of worrying declines is encouraging, and the dataset provides a valuable baseline for future monitoring.

6.2 How do our results compare with other similar schemes?

We are not aware of other areas in Tanzania, or Africa where community level monitoring has been paired to FSC-certified logging and where biodiversity data has been gathered with an ongoing extraction of valuable timber trees. Community forest monitoring has been documented in other contexts, including REDD+ and carbon finance schemes, where locally collected data has proven reliable and cost-effective (Katani et al., 2016; Pratihast et al., 2014). Community science infrastructure nonetheless remains sparse across much of the Global South, with persistent challenges related to limited technology infrastructure, unbalanced knowledge hierarchies, and insufficient data governance (Benyei et al., 2023; Elias et al., 2023)

6.3 How can this analysis inform forest management?

Within the study area, MCDI, village authorities, or local government could use the RStudio script created as part of this study to continue to gain insights into how forest management initiatives affect species communities. This could facilitate a continuous feedback loop between MCDI and the VNRCs that could further strengthen sustainable forest use and conservation (Reid et al., 2009).

The spatial analysis indicates that encounter rates show no clear relationship with proximity to Nyerere National Park or other protected areas, suggesting that the VLFRs function as habitat extensions beyond the formal protected area boundaries and may play an important role in maintaining viable populations of threatened species. These findings have direct relevance for informing district-level land-use planning.

6.4 Integrating the Monitoring Data into National Conservation Frameworks

Tanzania's latest National Biodiversity and Strategic Action Plan (NBSAP) 2025-2030 aims to reduce biodiversity loss and improve community livelihoods (DoE, 2025). These are objectives that aligns with those of MCDI (MCDI, 2024), making the potential for data uptake into NBSAP implementation significant. Community-based monitoring has proven able to complement scientific data at local scales where scientists and government institutions cannot always procure information (König et al., 2021; Rebecca et al., 2017), and MCDI's two decades of established networks and institutional relationships in Kilwa and Rufiji districts provide a strong foundation for this (Reid et al., 2009)

On a broader scale, the data could contribute to indicators tracking progress on global biodiversity objectives, including SDG 15 'Life on Land' and Kunming-Montreal global biodiversity agreement Target 10 'Sustainably manage agriculture, aquaculture, fisheries, and forestry areas' (CBD, 2022; Danielsen et al., 2024; DoE, 2025; United Nations, 2025; URT, 2021).

6.5 Limitation of Results

Despite strong efforts to be objective in this analysis, some limitations warrant consideration. As citizen scientists continue to participate in monitoring programs over time, skills and knowledge may improve, potentially inflating detection rates independent of genuine changes in species abundance (Farr et al., 2022; Serret et al., 2019). Participants familiar with their local forests may also be more likely to locate species in known local hotspots, introducing a spatial bias towards areas of prior detection (Kays et al., 2021).

The amount of funding available to MCDI has fluctuated over the years leading to variation in VNRC monitoring effort. Changes in MCDI staff and VNRC members may have resulted in loss of knowledge, or methodological inconsistencies. As data has been gathered by different groups of citizen scientists, variation in collection methods and skill-level among participants, may have influenced the results (Fraisl et al., 2022).

6.6 Recommendations for further enhancing the community-based monitoring program

Based on our analysis, we have identified four areas where targeted improvement by MCDI and the villagers could further enhance data quality and program effectiveness:

- Facilitate patrols are conducted at quarterly intervals

- Ensure consistency when filling out paper forms, and when transferring information from paper to digital format
- Reassess the suitability of the current selection of indicator species
- Regularly evaluate the approach undertaken, including the division of monitoring responsibilities and benefits across community members, how the data and results are used, and the communication with relevant stakeholders and policymakers, and adjust the objectives and activities of the community-based monitoring as needed

Equipping the VNRCs with sturdy smartphones or similar devices could enable real-time data entry and directly upload to an online database once connected to Wi-Fi (Benyei et al., 2023; Fraisl et al., 2022), minimizing the number of hands involved in data handling. MCDI previously tried piloting this approach, but the project was hampered by the fragility of the smartphones – emphasizing the need for sturdier equipment.

Adapting a digital format compatible with online databases, such as the Global Biodiversity Information Facility (GBIF) (GBIF.org, 2020), would improve the availability of monitoring data beyond the scope of MCDI and the FSC, but it would require than an agreement on data ownership could be made with the GBIF (Fraisl et al., 2022).

Lastly, to ensure the continued quality and relevance of the data, annual review of the data and patrol protocols by a professional scientist would be beneficial, with a more thorough assessment every five years to coincide with the renewal of the forest inventory and management plans. This would help ensure the approach remains effective and aligned with current local and national priorities (Fraisl et al., 2022).

7 Conclusions

Broadly these results suggest that the forests and woodlands in the study area have importance for species that are in decline globally, and have retained much of this importance over time despite logging and other pressures. The continued presence of globally threatened mammals and birds across monitored locations is encouraging, and the dataset provides a valuable baseline for detecting future change.

Our findings suggest that community-based biodiversity monitoring by citizen scientists can function effectively within a formal certification framework. That the data had not been fully analysed prior to this study underscores the need for continued analytical capacity alongside data collection capacity in NGOs facilitating forest certification efforts to overcome the challenge of translating community-collected data into actionable conservation and management decisions.

With targeted improvement to patrol regularity, data management and use, and periodic professional scientist review, the monitoring program has strong potential to inform both local forest management and national biodiversity reporting – and offers a replicable example of how community science can be integrated into sustainable forest governance.

Supplementary File

Appendix 1: Full list of locations

Appendix 2: List of recorded taxa

Appendix 3: Data collection and preprocessing

Global Research Collaboration Statement

This research emerged from a community-university partnership. The Mpingo Conservation and Development Initiative (MCDI) and the villagers in 10 communities in Kilwa and Rufiji districts, Tanzania, independently initiated and implemented the community-based biodiversity monitoring activities examined in this study. They approached the university team requesting technical support to analysing and interpreting the community-collected data on mammals and birds to inform management of the timber production areas and to further develop the community-based monitoring programme. The MCDI and the participating villagers retained decision-making authority throughout the research process, including site selection, study objectives, and data interpretation. The university team served in an advisory capacity, providing technical expertise in study design, statistical analysis and visualization. All activities were approved by the MCDI. Data ownership resides with the MCDI and the participating villagers.

Authors' Contributions Statement

Mpingo Conservation & Development Initiative (MCDI) participants collected the data, facilitated community organization, meetings and training exercises, and engaged with the other authors in conceptualizing the study. Katjia Akeena Dawila, Neil David Burgess and Jasper Makala led the liaison between community members and scientists, and the formal analysis. Søren Brofeldt assisted with analysis, software and visualization. Glory Massao organised field data collection, data curation and input to the database. Finn Danielsen and Ida Theilade provided guidance, acquired funding and contributed to writing, review and editing.

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Data Availability

The data underlying this study are maintained by the Mpingo Conservation & Development Initiative (MCDI) in partnership with the communities and stored in MCDI's online databases. The cleaned dataset used for analysis is publicly available on Dryad at DOI: 10.5061/dryad.xgxd254ws. Requests for access to the original data should be directed to MCDI at www.mpingoconservation.org. The R code used for analysis is available upon request to the first author.

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