An Evaluation of 15 Years of Community-Based Monitoring in Forest Stewardship Council Certified Forest Areas in Southern Tanzania: Insights from Mammal and Indicator Bird Species

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Abstract:
Certified community-managed forests are rare in East Africa, and the use of community-based biomonitoring to track biodiversity change in such forests is rarer still. We analyse 15 years of community-collected data on mammals and indicator bird species from 10 village land forest reserves in southern coastal Tanzania, managed under a Forest Stewardship Council certification scheme facilitated by Mpingo Conservation and 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 mammals and indicator 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 these community-managed forests function as important habitats. Our findings demonstrate that community-elected committees of forest users can generate highly valuable biodiversity data over sustained periods within a formal certification framework, and recommendations are made for improvements to data collection and management to strengthen the programme going forward.

Introduction

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 and 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).The miombo woodlands cover over two-thirds of the country as seen in Figure 1*a*, supporting large mammal populations and millions of people through forest products and ecosystem services (Abdallah and Monela, 2007, FBS, 2024).

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 and 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, McNicol et al., 2023).

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 (FBD, 2022, URT, 2007, Blomley and Iddi, 2009). CBFM has been supported by the Tanzanian government and international development agencies, with NGOs and Local Authorities as primary drivers of implementation (FAO, 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 (MNRT, 2007). CBFM-managed forests have shown low rates of forest loss, good management effectiveness, and better conservation outcomes than open forest lands and government reserves (Blomley and Iddi, 2009, FAO, 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).

In this paper we analyse community-collected observations of mammals, and three bird species selected as indicators of ecosystem health, in the coastal forests and miombo woodlands managed by villages in southern coastal Tanzania. 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.

The role of communities in forest monitoring

Community-based monitoring has proven a cost-effective tool that empowers local communities, delivers data quality comparable to that of professional scientists, and supports appropriate management interventions at the local scale (Danielsen et al., 2005, Benyei et al., 2023, 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 high quality 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 and Jussila, 2010).

In practice, this theoretical foundation is operationalised trough 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 (MNRT, 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., 2009). The results of such schemes are rarely explored, often because they have not yet generated sufficient data for analysis (Yanda et al., 2025, Blomley et al., 2008, Danielsen et al., 2021).

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, FSC, 2025).
Monitoring the FSC outcomes is necessary to assess effectiveness. While FSC-certification has 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, Trolliet et al., 2019, Mathias et al., 2023).

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 citizen 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 citizen science in the Global South.

Study Site

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*a*; 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.

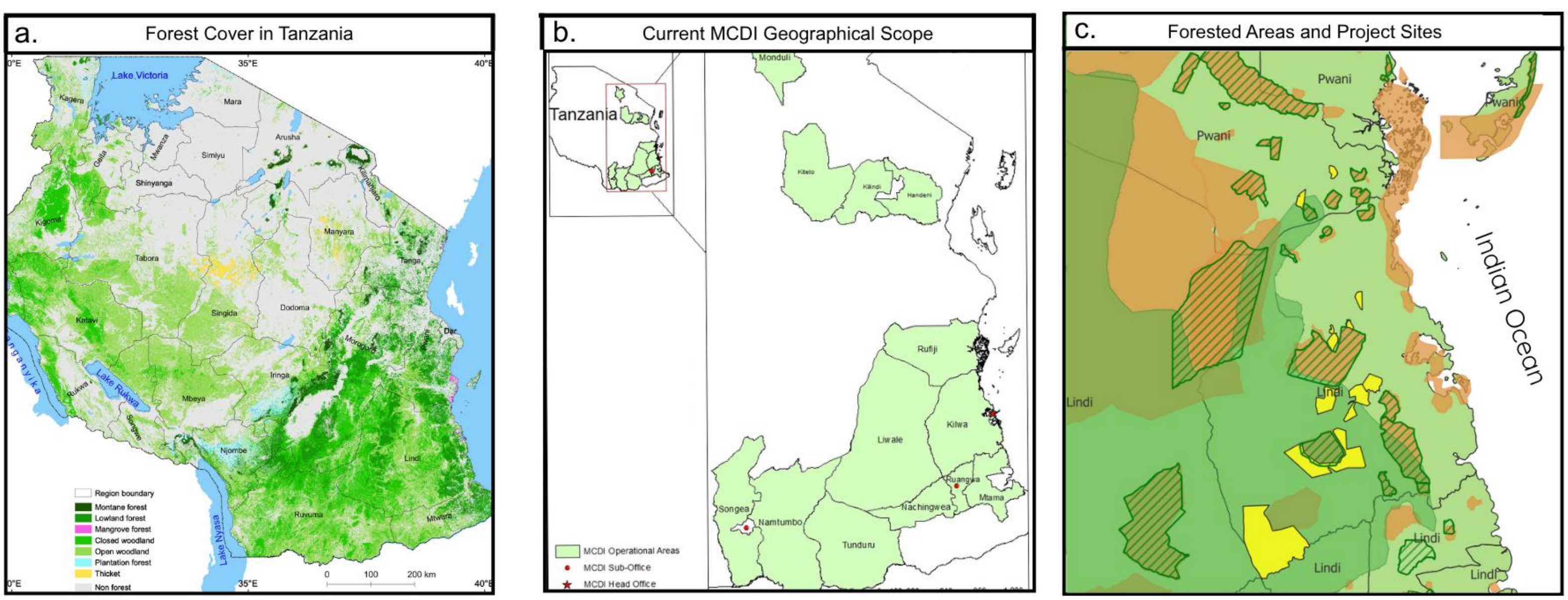

Figure 1: Location of the study area and monitoring site in Tanzania. (a) shows national forest cover (TFS, 2025); (b) shows the geographical distribution of MCDI project sites (adapted from MCDI, 2024); (c) shows the primary forest types (miombo woodlands: green; coastal forests: hatched), protected 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 amphibians 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 and 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 mean annual rainfall of 600-1000 mm, mean that canopy trees lose their leaves seasonally and 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).

Institutional setting for community-based biomonitoring

Mpingo Conservation and Development Initiative (MCDI), a local Non-Government Organization, was founded in 1995 with a permanent base in 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 programmes. The goal has been to make these operations self-sustaining from the income generated by their logging revenue, while fostering a positive relationship between communities and biodiversity conservation by providing an economic alternative to forest conversion for agriculture.

Fourteen villages across three districts (see Figure 1*c*) have been FSC-certified under MCDI's group certification since initial implementation in 2009, covering an area of 192,068 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 biomonitoring in their forest. The certification further requires that CBFM villages declare at least 10% of their certified VLFR as a no-take conservation zone.

Methods:

Study Design

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

Biomonitoring:

After initial training and support by MCDI, biomonitoring has been conducted by the VNRCs through regular patrols in their respective VLFR. The number of villages participating in the monitoring varies over time, as does the duration of their monitoring, as illustrated in Figure 2. Four villages were excluded from the analysis due to insufficient data, leaving 10 villages for further analysis (see Supplemental file: Appendix 1 for an overview of included and excluded villages).

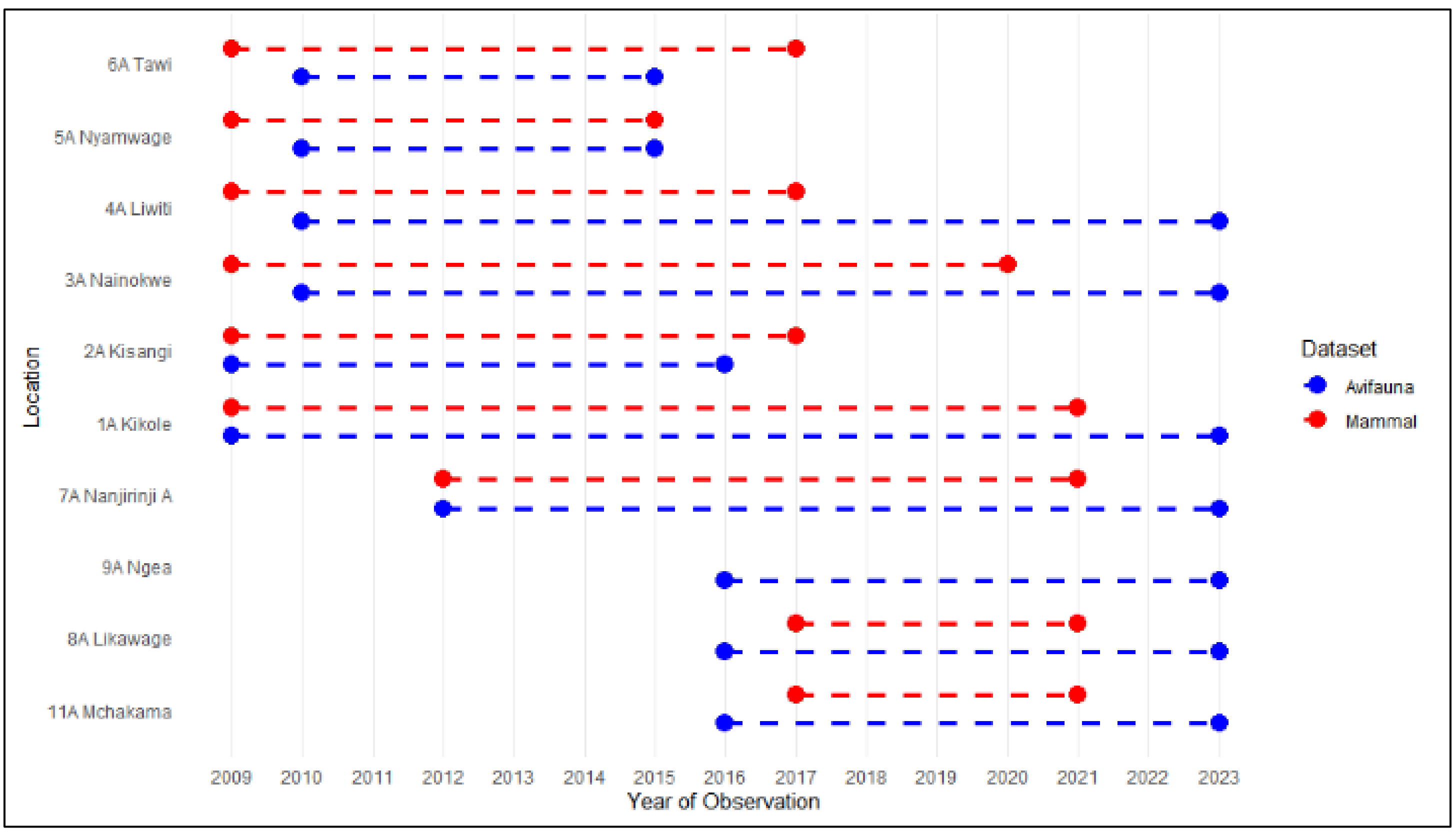

Figure 2: Timeline showing the first and last year of reported mammal monitoring data (red) and indicator bird species data (blue) for each village location, spanning the period 2008–2023.

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 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 capenis*, Crested Guineafowl (CG) – *Guttera pucherani,* and Dark-backed Weaver (DBW) – *Ploceus bicolor*. These were selected 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). Across all districts, the mammal dataset contains 1,924 encounters recorded over 536 patrols, covering 30 species. The avifauna dataset contains 3,061 encounters across 508 patrols, limited to the three indicator species.

<u>Mapping in GIS:</u>
To establish an overview of the geographical distribution of the locations involved in data collecting, a map, Figure 1*c,* 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 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.

<u>Fieldwork</u>
The lead author visited the MCDI main office in Kilwa Masoko during October to November 2024, facilitating fieldtrips, working with existing data, and undertaking interviews with key staff. MCDI co-authors have undertaken field visits to the villages and forests studied here on numerous occasions over approximately 15 years, and the last author (NDB) has visited on two occasions. MCDI has since initial project implementation, supported the involved communities in data collection through workshops, training activities, and participation in village meetings.

Analytical Methods

Initial data preprocessing was conducted in Excel to assess quality and reliability prior to analysis (see Supplemental 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 authors involved in data analysis. To account for uneven sampling, data were standardised by patrol effort, grouping entries by date and location.

Locations with ≤2 years of monitoring (n=6) 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 species, 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 species and presented alongside IUCN global population trends for comparison.

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.

Species-specific detection frequency was calculated as the percentage of total patrols on which each species was recorded across all locations, with total encounter count noted alongside. Species 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.

Results

<u>Encounter rates increased over time with no significant seasonal variation</u>

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, $p = 0.42$), 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* $p = 0.34$, *Avifauna* $p = 0.61$), as demonstrated by the violin plots in Figure 3, with broadly comparable sample sizes across seasons (*Mammals*: 113–237 patrols; *Avifauna*: 112–222 patrols).

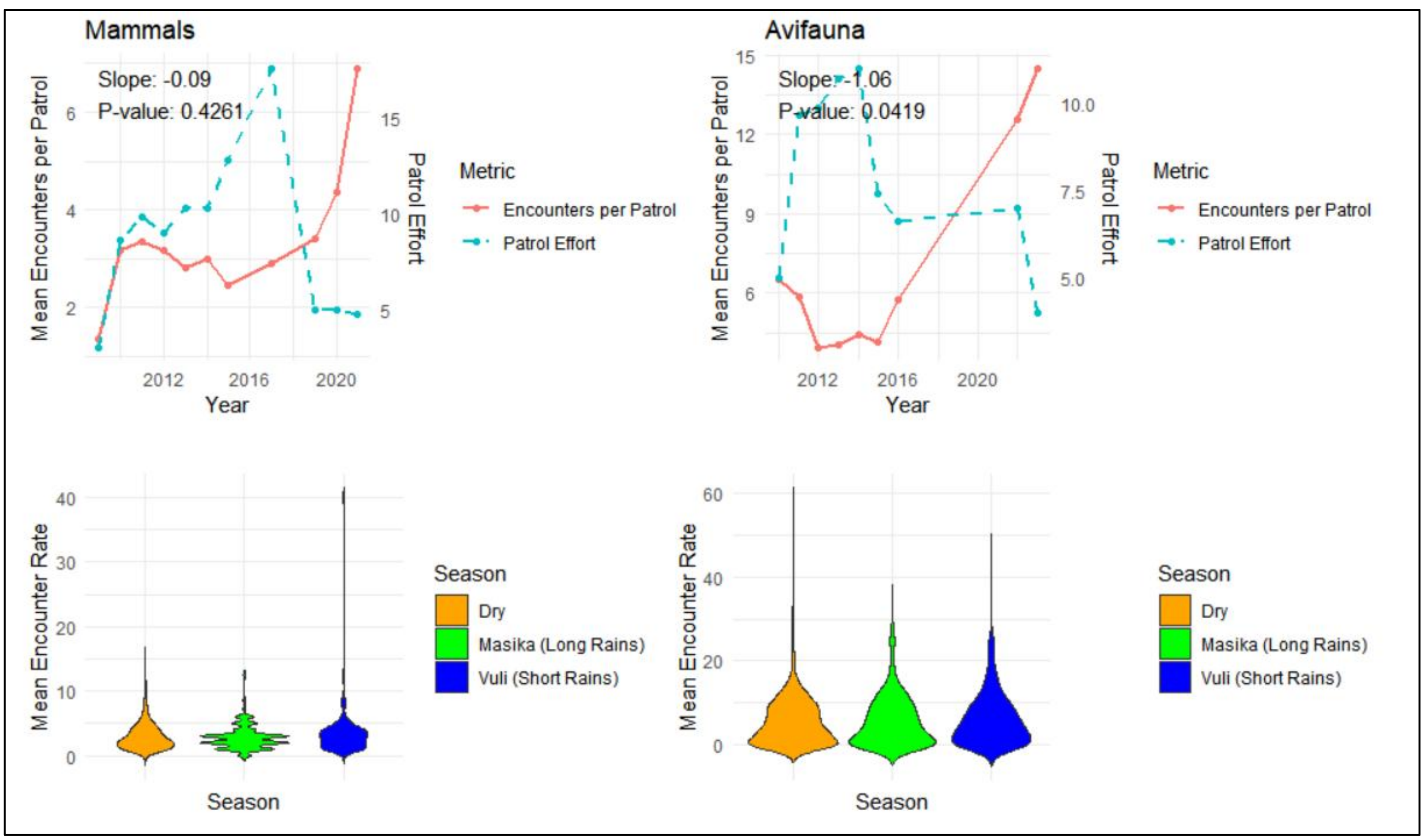

Figure 3: Top: Linear regression of encounter rate against patrol effort across years for mammals (2009-2021) and avifauna (2010-2023). Bottom: Violin plots illustrating the distribution of encounter rates across seasons for both datasets.

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 species. Local trends are based on linear regression of encounter rates over time; only species with $R^2 > 0.50$ are included to ensure reliable trend estimates.

Species (common)	Species (scientific)	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	201-2021 (10)	LC		0.067	Stable
Dik dik	*Madoqua kirkii*	20.00	2010-2017 (7)	LC		0.014	Stable
Raven	NA	14.77	2010-2021 (9)	NA		0.028	Decreasing
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)	NT		0.149	Decreasing
Hartebeest	*Alcelaphus lichtensteinii*	7.90	2010-2021 (10)	LC		0.122	Decreasing

Elephant shrew	NA	7.83	2009-2021 (10)	NA		0.073	Decreasing
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**	Stable
Hippopotamus	*Hippopotamus amphibius*	3	2011-2021 (9)	VU		0.061	Stable
Porcupine	*Hystrix cristata*	3	2010-2015 (4)	NA		0.449	NA
Rabbit/hare	NA	2.28	2011-2021 (7)	NA		0.298	Stable
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	Decreasing
Crested Guineafowl	*Guttera pucherani*	96.88	2010-2023 (9)	LC	4.530	**0.604**	Stable

IUCN Red List species 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 (16) (see Supplemental file: Appendix 1 for full species list and IUCN categories).

Least Concern species accounted for the highest average encounter rate with 1.50 encounters per patrol, followed by Endangered (1.06), Near Threatened (0.53) and Vulnerable species (0.29).

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.

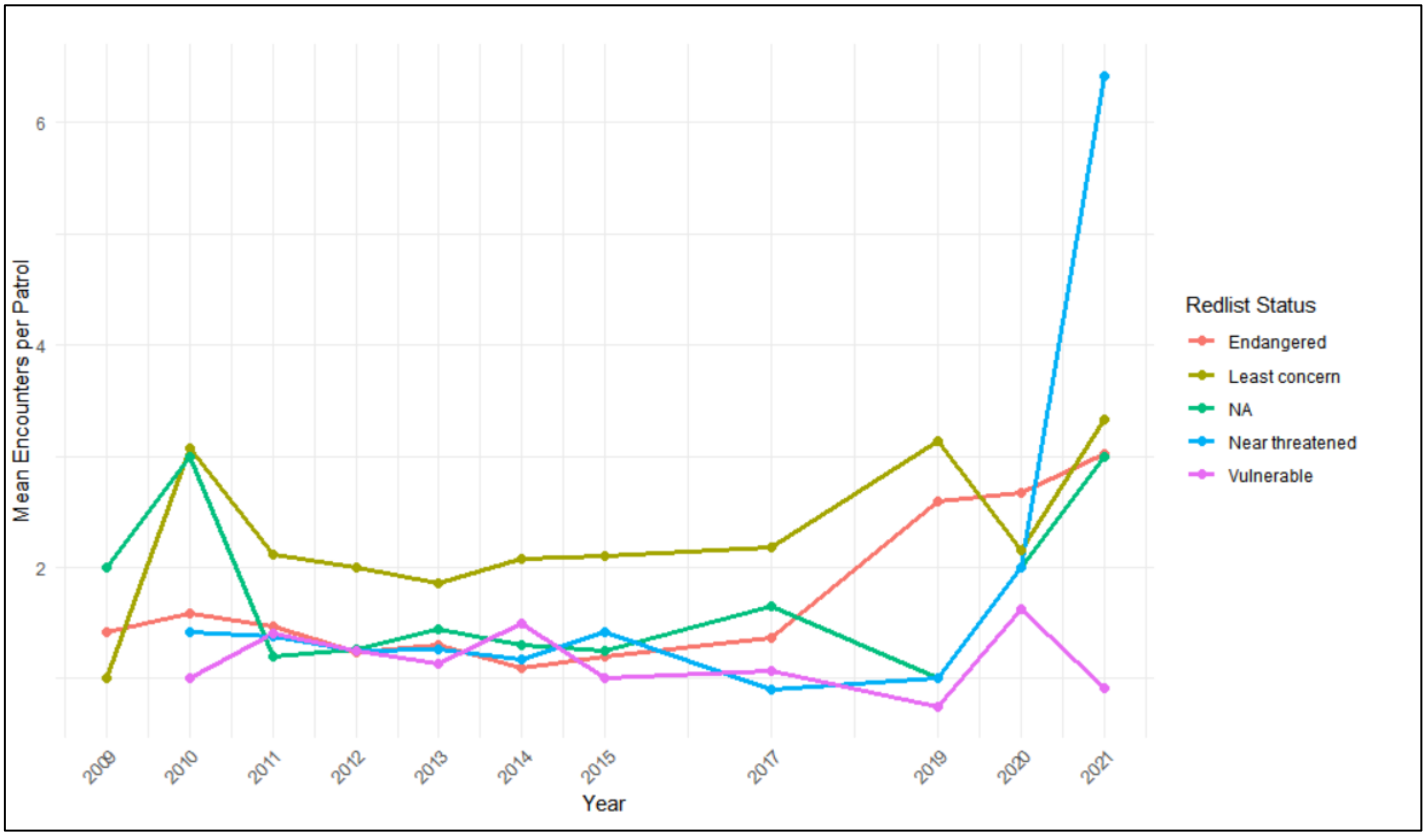

Figure 4: Temporal trend in mean encounters per patrol across IUCN Red List categories for mammal species, spanning the period 2009-2021. N/A indicates species that could not be identified to species level or for which IUCN status information was unknown.

Detection frequency varied considerably across species 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 species (23 of 30) were recorded in fewer than 10% of the patrols, with 7 species exceeding this threshold.

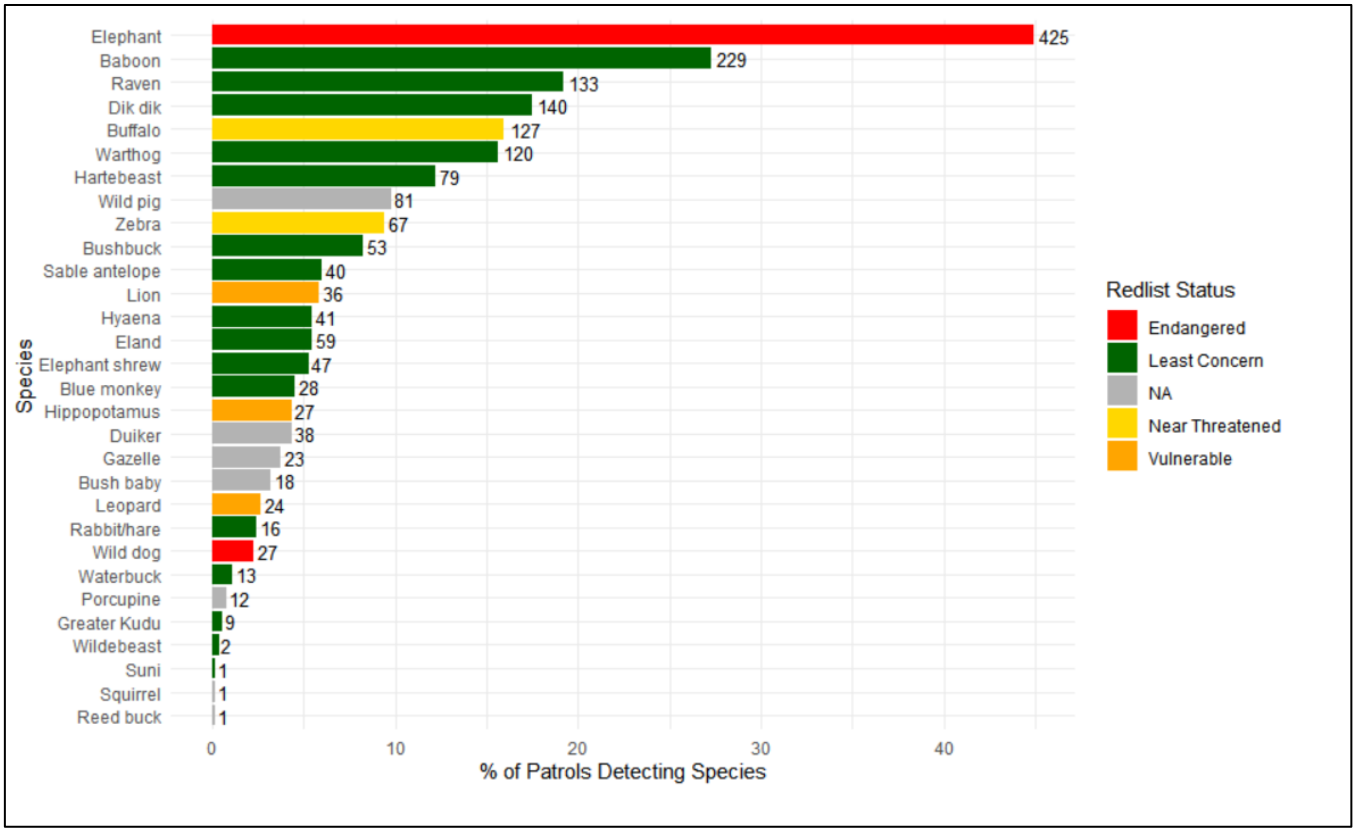

Figure 5: Percentage of patrols detecting each mammal species across the monitoring period, with total encounter counts labelled. Species are coloured by IUCN Red List Status. N/A indicates species that could not be identified to species level or for which IUCN status information was unknown.

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* ($\chi^2 = 0.83$, df = 2, $p = 0.66$) or *Avifauna* ($\chi^2 = 0.49$, df = 2, $p = 0.78$). For M*ammals*, median encounter rates were 3.5 (IQR 2.50) in harvest zones and 3.0 (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 similarly comparable across zones (HZ: 3, IQR 6; NTZ: 3, IQR 7).

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* (ρ = 0.44, $p = 0.23$) or *Avifauna* (ρ = 0.12, $p = 0.74$). Similarly, no significant relationship was found between encounter rates and distance to Nyerere National Park for mammals (ρ = -0.22, $p = 0.58$) or avifauna (ρ = 0.45, $p = 0.19$).

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.

What do the results tell us?

Our evaluation of the community-collected data reveals encouraging results about the condition of these forests, which have been managed through selective logging, and subject to other pressures such as poaching of elephants for ivory and 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 programme 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 potential declines in 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.

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 (Pratihast et al., 2014, Katani et al., 2016). Citizen 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, Pocock et al., 2018).

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, which enables considerably more detailed analysis than presented here, to gain ongoing insights into how forest management initiatives affect species communities, including comparisons of mammal species richness and diversity between districts and forests. This could facilitate a continuous feedback loop between MCDI and the VNRCs that, if characterized by mutual trust and effective communication, could cement the potential for future sustainable conservation in the decades to come (Reid et al., 2009).

The spatial analysis further 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 rare and wide-ranging species.

These findings have direct relevance for district-level land-use planning, and together with MCDI's practical approach to forest management, could guide broader resource management while improving management responses and the speed of decision-making (Danielsen et al., 2010, König et al., 2021).

Integrating the Biomonitoring Data into National Conservation Frameworks

Tanzania's latest National Biodiversity and Strategic Action Plan (NBSAP) 2015-2020 aims to reduce biodiversity loss and improve community livelihoods (DoE, 2015). Objectives that align with those of MCDI (MCDI, 2024), making the potential for data uptake into policy significant (DI, 2017).

Citizen science has proven effective in complementing scientific data at local scales where government institutions cannot always procure timely information on local priorities (DI, 2017, König et al., 2021), and MCDI's two decades of established networks and institutional relationships in Kilwa district 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 and Convention on Biological Diversity goals (CBD, 2022, DoE, 2015, Tanzania, 2021, sdgs.un.org/goals, Danielsen et al., 2024).

Limitation of Results

Factors found to increase the accuracy of citizen science data, such as project longevity and socio-economic interests, are already present among the CBFM participants of this study, although not all locations have been involved for equally long durations (Aceves-Bueno et al., 2017, Yanda et al., 2025).

However, several limitations warrant consideration. As citizen scientists continue to participate in monitoring programmes 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 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).

Recommendations for Improved Data

To ensure lasting engagement and reliable data, citizen science projects require a clear objective, inclusive and equitable participation that ensures monitoring responsibilities and associated benefits are shared fairly across community members, continued capacity building and training, and robust data quality assurance. Continued efforts to strengthen local data ownership, address ethical considerations, and maintain integration and communication with relevant stakeholders and policy-makers are all crucial aspects (Benyei et al., 2023, Elias et al., 2023, Kosmala et al., 2016). MCDI's monitoring program already incorporates many of these elements, and areas where gaps in the programme exist appear to be recognised and actively targeted.

However, practical and financial limitations have so far constrained progress. Based on the analysis conducted in this study, the following areas have been identified where targeted improvements could enhance data quality and program effectiveness:

- Ensure patrols are conducted at regular quarterly intervals
- Ensure consistency when filling out paper forms
- Ensure consistency when transferring information from paper to digital format
- Reassess the suitability of current indicator species
- Evaluate the approach and further sharpen the objectives of the participatory monitoring

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 piloted 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 greatly improve the availability of biomonitoring data beyond the scope of MCDI and the FSC, although challenges regarding data ownership would need to be addressed (Fraisl et al., 2022).

Lastly, to ensure the quality and continued 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).

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 indicator bird species across monitored locations is encouraging, and the dataset provides a valuable baseline for detecting future change.

Our findings suggest that community-based 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 and highlights the broader challenge of translating community-collected data into actionable conservation and management decisions.

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

Supplementary File
Appendix 1: Full list of locations
Appendix 2: Species list
Appendix 3: Data collection and preprocessing

Data Storage
The data underlying this study are maintained by Mpingo Conservation and Development Initiative (MCDI) and stored in their online databases. Request for access to the data should be directed to MCDI at www.mpingoconservation.org.

Ethics Statement
This study is based on existing biodiversity monitoring data collected by community members as part of an established forest management programme. Data collection was conducted with the knowledge and consent of participating communities, with the approval and support of MCDI.

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Authors' Contributions Statement
KAD, NDB and JM designed and conducted the study. SB assisted with analysis. GM organised field data collection and input to database in the MCDI office. FD and IT provided guidance and comments on the paper. All authors helped shape the final paper.

References

ABDALLAH, J. M. & MONELA, G. G. 2007. Overview of Miombo Woodlands in Tanzania.

ACEVES-BUENO, E., ADELEYE, A. S., FERAUD, M., HUANG, Y., TAO, M., YANG, Y. & ANDERSON, S. E. 2017. The accuracy of citizen science data: a quantitative review. *The Bulleting of the Ecological Society of America,* 98.

BENNETT, N. J., WHITTY, T. S., FINKBEINER, E., PITTMAN, J., BASSETT, H. & GELCICH, S. 2018. Environmental stewardship: a conceptual review and analytical framework. *Environmental Management,* 61.

BENYEI, P., SKARLATIDOU, A., ARGYRIOU, D., HALL, R., THEILADE, I., TURREIRA-GARCÍA, N., LATRECHE, D., ALBERT, A., BERGER, D., CARTRÓ-SABATÉ, M., CHANG, J., CHIARAVALLOTI, R., CORTESI, A., DANIELSEN, F., HAKLAY, M. M., JACOBI, E., NIGUSSIE, A., REYES-GARCÍA, V., RODRIGUES, E., SAUINI, T., SHADRIN, V., SIQUEIRA, A., SUPRIADI, M., TILLAH, M., TOFIGHI-NIAKI, A., VRONSKI, N. & WOODS, T. 2023. Challenges, strategies, and impacts of doing citizen science with marginalised and indigenous communities: reflections from project coordinators. *Citizen Science: Theory and Practice,* 8.

BLOMLEY, T. & IDDI, S. 2009. Participatory forest management in Tanzania: lessons learned and experiences to date.

BLOMLEY, T., PFLEIGNER, K., ISANGO, J., ZAHABU, E., AHRENDS, A. & BURGESS, N. 2008. Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania *Oryx*.

BURGESS, N. D., MALUGU, I., SUMBI, P., KASHINDYE, A., KIJAZI, A., TABOR, K., MBILINYE, B., KASHAIGILI, J., WRIGHT, T. M., GEREAU, R. E., COAD, L., KNIGHTS, K., CARR, J., AHRENDS, A. & NEWHAM, R. L. 2017. Two decades of change in state, pressure and conservation responses in the coastal forest biodiversity hotspot of Tanzania. *Oryx,* 51.

CBD 2022. Decision adopted by the conference of the parties to the convention on biological diversity: 15/4. Kunming-Montreal global biodiversity framework.: Convention on Biological Diversity.

CONSERVATION.ORG. 2025. Conservation International. Available: https://www.conservation.org/priorities/biodiversity-hotspots [Accessed 26/04 2025].

DANIELSEN, F., ALI, N., ANDRIANANDRASANA, H. T., BAQUERO, A., BASILIUS, U., DE ARAUJO LIMA CONSTANTINO, P., DESPOT-BELMONTE, K., FREDERIKSEN, P. O., ISAAC, M., JAKOBSEN, P., KLIMMEK, H., MAPENDEMBE, A., MENG, H., SCHMIDT-VOGT, D., SOPHAT, S., SULYANDZIGA, R., VIRNIG, A. L. S., ZHANG, D. & BURGESS, N. D. 2024. Involving citizens in monitoring the Kunming–Montreal Global Biodiversity Framework. *Nature Sustainability,* 7**,** 1730-1739.

DANIELSEN, F., BURGESS, D. N., JENSEN, P. M. & PIRHOFER-WALZL, K. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *Journal of Applied Ecology,* 47**,** 1166-1168.

DANIELSEN, F., BURGESS, N. D., BALMFORD, A., DONALD, P. F., FUNDER, M., JONES, J. P. G., ALVIOLA, P., BALETE, D. S., BLOMLEY, T., BRASHARES, J., CHILD, B., ENGHOFF, M., FJELDSÅ, J., HOLT, S., HÜBERTX, H., JENSEN, A. E., JENSEN, P. M., MASSAO, J., MENDOZA, M. M., NGAGA, Y., POULSEN, M. K., RUEDA, R., SAM, M., SKIELBOE, T., STUART-HILL, G., TOPP-JØRGENSEN, E. & YONTEN, D. 2009. Local Participation in natural resource monitoring: a characterization of approaches. *Conservation Biology,* 25.

DANIELSEN, F., ENGHOFF, M., POULSEN, M. K., FUNDER, M., JENSEN, P. M. & BURGESS, D. N. 2021. The concept, practice, application, and results of locally based monitoring of the environment. *BioScience,* 71.

DANIELSEN, F., JENSEN, A. E., ALVIOLA, P., BALETE, D. S., MENDOZA, M. M., TAGTAG, A., CUSTODIO, C. & ENGHOFF, M. 2005. Monitoring Matters: Examining the Potential of Locally-based Approaches. *Biodiversity and Conservation,* 14**,** 2507-2542.

DAWSON, N. M., COOLSAET, B., STERLING, E. J., LOVERIDGE, R., GROSS-CAMP, N. D., WONGBUSARAKUM, S., SANGHA, K. K., SCHERL, L. M., PHAN, H. P., ZAFRA-CALVO, N., LAVE, W. G., BYAKAGABA, P., IDROBO, C. J., CHENET, A., BENNET, N. J., MANSOURIAN, S. & RODSADO-MAY, F. J. 2021. The role of Indigenous peoples and local communities in effective and equitable conservation. *Ecology and Society* 26.

DI 2017. Citizen-generated data and sustainable development: evidence from case studies in Kenya and Uganda. Development Initiatives.

DOE 2015. National Biodiversity Strategy and Action Plan (NBSAP) 2015-2020. Division of Environment: The united republic of Tanzania Vice President's Office.

ELIAS, P., SHONOWO, A., DE SHERBININ, A., HULTQUIST, C., DANIELSEN, F., COOPER, C., MONDARDINI, M., FAUSTMAN, E., BROWSER, A., MINSTER, J.-B., VAN DEVENTER, M. & POPESCU, I. 2023. Mapping the landscape of citizen science in Africa: assessing its potential contributions to sustainable development goals 6 and 11 on access to clean water and sanitation and sustainable cities. *Citizen Science: Theory and Pratice,* 8.

FAO 2019. Status of community-based forestry and forest tenure in the United Republic of Tanzania. Rome, Italy.

FARR, C. M., NGO, F. & OLSEN, B. 2022. Evaluating data quality and changes in species identification in a citizen science bird monitoring project. *Citizen Science: Theory and Practice,* 8.

FBD 2022. Participatory forest management in mainland Tanzania - facts and figures. Ministry of Natural Resources and Tourism.

FBS. 2024. *Miombo woodlands ecosystem* [Online]. Available: https://www.forestbeekeeping.co.tz/where-we-work/miombo-woodland-ecosystems/ [Accessed 21/04 2025].

FRAISL, D., HAGER, G., BEDESSEM, B., GOLD, M., HSING, P.-Y., DANIELSEN, F., HITCHCOCK, C. B., HULBERT, J. M., PIERA, J., SPIERS, H., THIEL, M. & HAKLAY, M. 2022. Citizen science in environmental and ecological sciences. *Nature Reviews Methods Primers,* 2.

FSC 2023. FSC principles and criteria for forest stewardship. *FSC-STD-01-001 V5-3 EN.*

FSC. 2025. *fsc.org* [Online]. Available: https://fsc.org/en [Accessed 01/08 2025].

GBIF.ORG. 2020. *GBIF Home Page* [Online]. Available: https://www.gbif.org [Accessed 11/04 2025].

KALONGA, S. K., MIDTGAARD, F. & KLANDERUD, K. 2015. Forest certification as a policy option in conserving biodiversity: an emperical study of forest management in Tanzania. *Forest Ecology and Managament,* 361.

KATANI, J. Z., MUSTALAHTI, I., MUKAMA, K. & ZAHABU, E. 2016. Participatory forest carbon assessment in south-eastern Tanzania: experiences, costs and implications for REDD+ initiatives. *Oryx,* 50.

KAYS, R., LASKY, M., PARSONS, A. W., PEASE, B. & PACIFIC, K. 2021. Evaluation of the spatial biases and sample size of a statewide citizen science project. *Citizen Science: Theory and Practice,* 6.

KÖNIG, A., PICKAR, K., STANKIEWICZ, J. & HONDRILA, K. 2021. Can citizen science complement official data sources that serve as evidence-base for policies and pratice to improve water quality? *Statistical Journal of the IAOS,* 37.

KOSMALA, M., WIGGINS, A., SWANSON, A. & SIMMONS, B. 2016. Assessing data quality in citizen science. *Frontiers in Ecology and the Environment,* 14.

MARTIN, E. & BURGESS, N. D. 2020. *Nothern swahili coastal forest* [Online]. One Earth Available: https://www.oneearth.org/ecoregions/northern-swahili-coastal-forests/ [Accessed 28/01 2025].

MATHIAS, G., GAGNACCI, F. & ROSALINO, L. M. 2023. FSC forest certification effects on biodiversity: a global review and meta-analysis. *Science of the Total Environment*.

MCDI 2017. MCDI Tanzania community-managed forests FSC group. *ED04 Forest Monitoring Procedures Manual.*

MCDI. 2024. *Mpingo Conservation & Development Initiative* [Online]. Available: https://www.mpingoconservation.org/ [Accessed].

MCNICOL, I. M., KEANE, A., BURGESS, D. N., BOWERS, S. J., MITCHARD, E. T. A. & RYAN, C. M. 2023. Protected areas reduce deforestation and degredation and enhance woody growth across African woodlands. *Communications Earth & Environment* 4.

MENG, H., CARR, J., BERADUCCI, J., BOWLES, P., BRANCH, W. R., CAPITANI, C., CHENGA, J., COX, N. A., HOWELL, K., MALONZA, P., MARCHANT, R. A., MBILINYE, B. P., MUKAMA, K., MSUYA, C. A., PLATTS, P. J., SAFARI, I.,

SPAWLS, S., SHENNAN-FARPON, Y., WAGNER, P. & BURGESS, D. N. 2016. Tanzania's reptile biodiversity: distribution, threats and climate change vulnerability. *Biological Conservation*.

MITTERMEIER, R., GIL, P., HOFFMANN, M., PILGRIM, J., BROOKS, T., MITTERMEIER, C., LAMOREUX, J. & FONSECA, G. 2004. Hotspots revisited. Earth's biologically richest and most endangered terrestrial ecoregions. *Conservation International,* 392.

MNRT 2007. Community-based forest management guidelines. *For the establishment of village lande forest reserves and community forest reserves.*

PIERCE, J. L. & JUSSILA, I. 2010. Collective psychological ownership within the work and organizational context: Construct introduction and elaboration. *Journal of Organizational Behavior,* 31.

POCOCK, M. J. O., CHANDLER, M. W. S., BONNEY, R., THORNHILL, I., ALBIN, A., AUGUST, T. A., BACHMAN, S. P., BROWN, P. M. J., CUNHA, D. G. F., GREZ, A. A., JACKSON, C., PETERS, M. A., RABARIJAON, N. R., ROY, H. E., ZAVIEZO, T. & DANIELSEN, F. 2018. A Vision for Global Biodiversity Monitoring With Citizen Science. *Advances in Ecological Research,* 59**,** 169-223.

PORTER-BOLLAND, L., ELLIS, E. A., GUARIGUATA, M. R., RUIZ-MALLÉN, I., NEGRETE-YANKELVICH, S. & REYES-GARCÍA, V. 2012. Community managed forest and forest protected areas: an assessment of their conservation effectivenss across the tropics. *Forest Ecology and Managament,* 268.

PRATIHAST, A. K., HEROLD, M., DE SY, V., MURDIYARSO, D. & SKUTSCH, M. 2014. Linkin community-based and national REDD+ monitoring: a review of the potential. 4.

RACT, C., BURGESS, N. D., DINESEN, L., SUMBI, P., MALUGU, I., LATHAM, J., ANDERSON, L., GEREAU, R. E., GONÇALVES DE LIMA, M., AKIDA, A., NASHANDA, E., SHABANI, Z., TANGO, Y., MTELEKA, S., SANTOS SILAYO, D., MWANGI, J., LYATUU, G., PLATTS, P. J. & ROVERO, F. 2024. Nature Forest Reserves in Tanzania and their importance for conservation. *PLOS ONE,* 19.

REID, R. S., NKEDIANYE, D., SAID, M. Y., KAELO, D., NESELLE, M., MAKUI, O., ONETO, L., KIRUSWA, S., OLE KAMUARO, N., KRISTJANSON, P., OGOTU, J., BURNSILVER, S. B., GOLDMAN, M. J., BOONE, R. B., GALVIN, K. A., DICKSON, N. M. & CLARK, W. C. 2009. Evolution of model to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa.

SDGS.UN.ORG/GOALS. *Sustainable Development Goals* [Online]. United Nations. [Accessed 09/05 2025].

SERRET, H., DEGUINES, N., JANG, Y., LOIS, G. & JULLIARD, R. 2019. Data quality and participant engagement in citizen science: comparing two approaches for monitoring pollinators in France and South Korea. *Citizen Science: Theory and Practice,* 4**,** 1.

SHEIK, A. P. & COOK, N. 2024. Biodiversity and conservation in Tanzania. Congressional Research Service.
TANZANIA, T. U. R. 2021. National five year development plan 2021/22- 2025/26.
TROLLIET, F., VOGT, M. & KLEINSCHROTH, F. 2019. How does FSC certification of forest management benefit conservation of biodiversity? *Sustainability Certification Schemes in the Agricultural and Natural Resource Sectors.* Routledge.
UNEP. 2025. Available: https://www.unep-wcmc.org/en [Accessed 30/1 2025].
URT 2007. Land use planning aAct. *In:* TANZANIA, G. O. T. U. R. O. (ed.).
YANDA, P., CHENGULA, F., KALOKOLA, R. & ALFRED, E. 2025. Forest governance in Tanzania: the case of Pangani district. Uongozi Institute.