

A Comparative Study of Species Richness and Abundance in Protected Areas of Malawi

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Abstract

Malawi is a country in southern Africa, with more than 50% of its population living in poverty. In most cases, people depend on natural resources to support their daily livelihoods. This heavy reliance on natural resources increases the threat to biodiversity richness and abundance. The aim of this study was to assess the current state of biodiversity richness and abundance in three protected areas—Mulanje Forest Reserve (Southern region), Lilongwe Nature Sanctuary (Central region), and Mzuzu Botanic Garden (Northern region)—and to evaluate the effectiveness of existing conservation efforts. Assessing species richness and abundance is crucial for determining population trends, informing conservation planning, and guiding monitoring programs in the management of protected areas (PAs). A cross-sectional, descriptive, and exploratory study using a mixed-method approach was carried out in these three protected areas. Data were collected through questionnaires and focus group discussions (FGDs) involving forest reserve managers, plant identification specialists, game rangers, and community members. Structured questionnaires and interview guides were used, and data were analysed using Microsoft Excel software. The results indicated low species richness and abundance in the protected areas, largely due to anthropogenic activities. These findings were supported by low diversity indices of 1.52, 1.18, and 1.13 for Mzuzu Botanic Garden, Mulanje Mountain Forest Reserve, and Lilongwe Nature Sanctuary, respectively. To reduce the impact of anthropogenic activities, day and night patrols should be intensified to prevent poaching and encroachment. Awareness campaigns highlighting the value of biodiversity could help reduce poaching and the smuggling of endangered species. Additionally, outreach programs in schools could foster a culture of appreciation for nature among students. Reforestation programs, the establishment of woodlots, and active community involvement in all aspects of biodiversity conservation in surrounding areas are essential. These measures would help alleviate the pressure on natural resources for communities living near protected areas.

1. Introduction

Biodiversity encompasses all the different kinds of life found in a particular area, including animals, plants, fungi, and even microorganisms such as bacteria. These species and organisms interact within ecosystems like an intricate web, maintaining balance and supporting life. Biodiversity refers to the variety of life on Earth in all its

forms, from genes and microorganisms to entire ecosystems [1]. The world's species diversity is estimated to range between 5 and 30 million species, though only about 4.67% of these have been formally described by scientists [2]. According to the World Biodiversity Council, approximately 1.74 million species of animals, plants, fungi, and microorganisms are currently known, as reported by the World Wildlife Fund [3]. However, biodiversity is declining rapidly, with a 73% reduction in animal population size since 1970 [3]. Wild mammals, in particular, have declined by 85% since the rise of humans [4]. These losses are largely driven by human activities such as deforestation, agricultural expansion, settlement, and poaching [4]. Currently, humans and livestock account for 96% of mammal biomass, leaving only 4% for wild mammals [5].

To ensure the continuity of species richness and abundance, several conservation measures have been implemented. These include the establishment of protected areas such as national parks, reintroduction programs for endangered species, sustainable agricultural practices, and restrictions on hunting and poaching. In Europe, improvements in species richness and abundance have been observed. Africa is home to one-sixth of the world's plant species and currently hosts 369 wetlands of national importance [6]. However, numerous factors threaten the survival of species in both marine and terrestrial habitats. Estimates suggest that climate change could cause the loss of over half of African bird and mammal species, as well as a 20–30% decline in lake productivity (the plant and animal life produced by a lake), according to the African Development Bank Group [7]. More than one million species of plants and animals are at risk of extinction; 40% of amphibians and 33% of reef-forming corals are endangered [7]. The combined effects of habitat loss, degradation, overexploitation of wildlife, illegal poaching, and invasive non-indigenous species are projected to be the primary drivers of biodiversity loss over the next 50–100 years [7]. Human behavior, particularly armed conflict, has also devastated biodiversity. Between 1946 and 2010, 70% of protected areas in Africa were affected by war, reducing populations of elephants, hippos, giraffes, and other large mammals as militants and local communities turned to hunting wild animals for bush meat and ivory [7].

Across Africa, nations have worked to strengthen biodiversity protection through the expansion of protected areas, covering 14% of land and 2.6% of marine areas [2]. Various rules and regulations have been established to safeguard sites of ecological importance, including wetlands, critical habitats, important bird and biodiversity areas, ecologically significant marine areas, community conserved areas, and biosphere reserves [2]. Governments and policymakers have also engaged local and Indigenous communities in managing and protecting natural resources and reserves [8].

Malawi, located in south-eastern Africa, is renowned for its rich biodiversity [9]. The country's unique geography, including the Great Rift Valley and Lake Malawi, supports diverse ecosystems such as forests, grasslands, and wetlands [9]. The National Red Data List of 2010 identified 248 species, of which 51.6% are considered threatened. Additionally, the Millennium Seed Bank Project conducted a conservation assessment of 63 species determined to be either at high risk of extinction or data deficient. The assessment found that 23 species could be classified as threatened according to IUCN Red List criteria [10]. Malawi's isolation of communities has led to species endemic not only to the lake but also to specific areas within it, driving unparalleled adaptive speciation of fish [11]. Climate change is further affecting Malawi's biodiversity, with rising temperatures and changing rainfall patterns altering ecosystems and disrupting species distributions [12].

According to Lal et al. [13], anthropogenic activities have severely impacted species richness and abundance in Sub-Saharan African countries, including Malawi. These impacts include habitat degradation and loss, overexploitation of resources, pollution, climate change, human-wildlife conflict, invasive species, and decline in endangered species such as lions and elephants [13]. Consequently, the key elements of Malawi's biodiversity are now largely confined to a small and diminishing set of protected areas, including forest reserves [13]. Large mammal populations have declined severely, even within protected areas, largely due to poaching [14–16]. For example, Kasungu and Nyika National Parks have experienced substantial poaching of large mammals [14]. The Department of Home Affairs (DHA) reports that poaching levels are higher than previously suspected, highlighting the urgent need for action [17]. Despite local and international conservation efforts, many species remain threatened with extinction [18].

Estimates suggest that the total number of species on Earth exceeds 15 million, potentially reaching 30 million or more [19]. Current species extinctions are primarily driven by high human population densities and intensive resource use [19]. Humans now appropriate about one-third of the gross primary production of terrestrial ecosystems [20]. Furthermore, urbanization, industrialization, and agricultural expansion significantly alter land use, causing deforestation, habitat fragmentation, and soil degradation [21].

Rhinos, listed as endangered, face severe threats due to human activities. According to the International Rhino Foundation (2024), the worldwide rhino population is estimated at fewer than 27,000 individuals, with around 1,000 rhino horns traded illegally each year [22]. Sumatran rhinos have experienced a 13% population decline, and Africa's white rhinos continue to decline due to poaching [22]. In Zambia, black rhinos, previously declared extinct in 1998, now have one of the fastest-growing populations on the continent [23]. Conservation efforts since the 1960s—including reintroduction from South Africa, provision of financial and technical support, establishment of intelligence-based protection units, and canine-assisted anti-poaching operations—have

contributed to this recovery [24, 25]. Monitoring ecological data and rhino populations has also informed effective conservation strategies [25]. Malawi is witnessing a resurgence of wildlife in its parks under progressive conservation policies that aim to restore natural heritage and provide social, economic, and environmental benefits [26].

Over the past 40 years, Mozambique has seen a significant decline in African elephant populations due to hunting, poaching, and agricultural development [27]. The introduction of a National Strategy and Action Plan for the Conservation and Management of Elephants has helped the country's elephant population recover to approximately 22,000 [27, 28].

In Kenya, illegal trade in tusks and horns poses a serious threat to elephants and rhinos [2]. The country has implemented interventions such as the National Biodiversity Strategy and Action Plan (NBSAP), Nationally Appropriate Mitigation Actions (NAMAs), and commitments to international agreements [29].

In Malawi, the African elephant (*Loxodonta africana*), which is globally endangered, is found in Kasungu and Liwonde National Parks, occasionally in Nyika National Park, Vwaza Marsh, and Nkhotakota Wildlife Reserve, and in Namizimu, Thuma, and Phirilongwe Forest Reserves, but is extinct in Majete Wildlife Reserve [30]. To address global biodiversity loss, the United Nations Development Programme (UNDP) and Global Environment Facility (GEF) support conservation through transboundary wildlife protection, policy and capacity development, combating illegal wildlife trade, terrestrial and marine area protection, and management of human-wildlife conflict [31]. They also enhance ecological connectivity and corridors, advocating for the conservation of 30% of Earth's lands and waters by 2030 [31]. UNDP provides technical and policy support for access to genetic resources and fair benefit-sharing under the Nagoya Protocol [31]. Since 2012, UNDP has contributed to implementing the Nagoya Protocol through multiple GEF-funded projects in over 50 countries. However, lack of public awareness and understanding of biodiversity limits conservation effectiveness [32, 33]. Education and outreach campaigns are crucial for fostering appreciation of biodiversity and motivating communities and governments to take action [31, 34].

Malawi's biodiversity comprises a variety of ecosystems and species [35]. A 1994 report by the Environmental Affairs Department indicated that the greatest species diversity is found in protected areas, including eighty seven (87) forest reserves, five (5) national parks, and four (4) wildlife reserves, covering 1.8 million hectares [35]. Many flora species are threatened but not yet assessed for the IUCN Red Data List due to insufficient information [36], highlighting the need for studies to generate baseline data on threatened species.

Challenges facing Malawi's flora include forest fires, elephant damage, and poor seedling survival [37]. For example, the total population of *Pterocarpus angolensis* is unknown, and quantitative data for Tanzania and Malawi are lacking [2]. To conserve these IUCN Red-Listed trees, Mozambique, Malawi, and Zambia banned log exports of Class 1 timber species in 2007, 2008, and 2014, respectively [38–40]. Malawi has also conducted public awareness campaigns through the Ministry of Natural Resources, Energy, and Mining, addressing the dangers of bushfires and forming part of the Sustainable Land Management (SLM) and Environment and Natural Resources Management (ENRM) projects [41, 42]. Additionally, legal instruments such as the Constitution of the Republic of Malawi (1995) and the Environment Management Act (EMA, 1996) provide protection for biodiversity [43].

Despite these efforts, conservation in Malawi faces multiple challenges [44]. These include insufficient human and institutional capacity, limited research on biodiversity, low public awareness, lack of community involvement, inadequate legislation, weak law enforcement, poor coordination among responsible institutions, and limited funding [45, 46]. Consequently, biodiversity loss continues globally and in Malawi. This study was therefore conducted to investigate the status of biodiversity in Mzuzu Botanic Garden, Lilongwe Nature Sanctuary, and Mulanje Mountain Forest Reserve, assess threats to biodiversity, and document strategies and challenges in conserving diverse life forms.

2. Research Methodology

2.1 Research Design

This study employed a mixed research method, an approach that involves collecting both quantitative and qualitative data, integrating the two types, and using distinct designs that may incorporate philosophical assumptions and theoretical frameworks. This approach provides a more comprehensive understanding of the complex interplay between environmental and social factors. For example, qualitative methods were used to gather information on people's attitudes, values, and approaches to managing species, ecosystems, and natural resources. In contrast, quantitative methods were employed to examine population sizes of key species over time [47], analyse patterns in community composition across habitats and regions, investigate the relationships between species abundance and habitat features, and study the links between human activities—such as land use and agriculture—and biodiversity indicators like species abundance and habitat loss [48].

2.2 Study Site

The study was conducted in three protected areas: Lilongwe Nature Sanctuary, Mzuzu Botanic Garden, and Mulanje Forest Reserve (Fig. 1). These sites were selected because they are located in districts experiencing rapid population growth, which increases pressure on natural resources. For example, according to the World Population Review, Lilongwe's population in 2025 is estimated at 1,393,010. In 1950, the population was only 3,909. The city has grown by 59,910 residents since 2024, representing an annual growth rate of 4.49% [49].

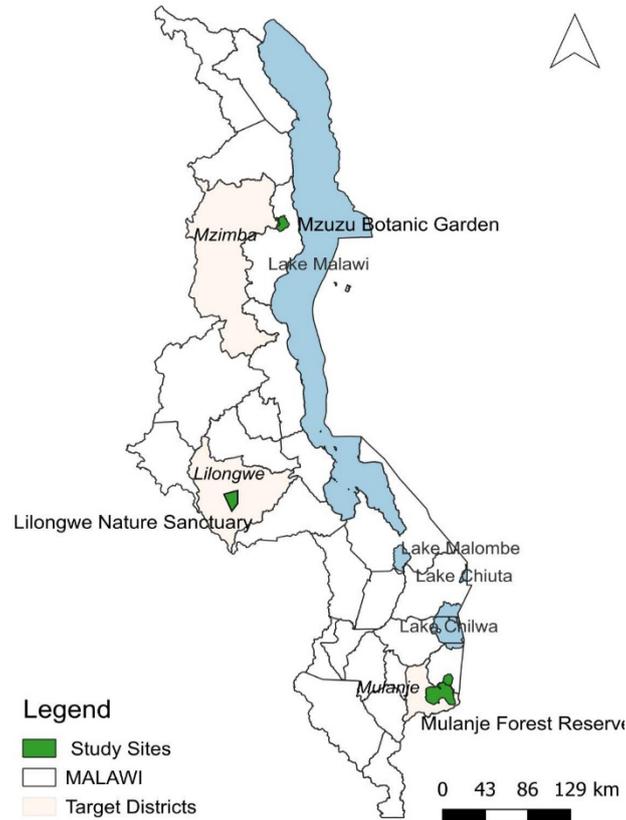


Fig. 1 Map of Malawi showing study locations

The World Population Review also estimates that the human populations of Mzuzu and Mulanje have experienced notable changes between 1950 and 2024. In 1950, the population of Mzuzu was approximately 10,000 residents, and by 2024 it had increased to around 220,000 residents [50]. This growth represents an average annual increase of about 4.2% over the 74-year period. In Mulanje district, the population grew from approximately 50,000 residents in 1950 to around 120,000 residents in 2024 [50].

2.3 Study Population

The study focused on three protected areas in Malawi: Mzuzu Botanic Garden (Northern region), Lilongwe Nature Sanctuary (Central region), and Mulanje Forest Reserve (Southern region). Participants included plant and animal species, forest reserve managers, forest guards, plant specialists, and people residing near the protected areas. Across all sites, both plant and animal classes were studied.

2.4 Sample Size

The study included seven plant species from Lilongwe, five from Mzuzu, and six from Mulanje. Human participants consisted of three forest reserve managers, three forest guards, three plant specialists, and three community members residing near the protected areas. Four animal classes were studied across all sites.

The inclusion of multiple forest reserves using a purposive sampling technique (Mzuzu, Lilongwe, and Mulanje) allowed for the collection of diverse ecological data, including habitat types, since each reserve has unique species compositions. Participants provided broad perspectives on research aspects, contributing to a comprehensive understanding of species richness at the national level [51]. The variation in plant species numbers across reserves (7 in Lilongwe, 5 in Mzuzu, 6 in Mulanje) and animal classes (4 across all sites) allowed

for assessment of biodiversity distribution and regional variation [52]. Furthermore, differences in species numbers highlighted the influence of local conditions, such as climate, soil, and elevation, on plant diversity [53]. Forest reserve managers, guards, and local residents provided valuable traditional and observational knowledge that complemented scientific data, offering insights into species distribution, behavior, and conservation challenges [54].

2.5 Sampling Technique

Purposive sampling, a non-probability sampling method, was employed to select participants based on relevant characteristics or expertise. Belt transects measuring 100 m by 50 m were established, and species presence and abundance were systematically recorded at regular intervals along these transects. This provided spatial data, enabling the identification of biodiversity patterns and variations across the study areas.

2.6 Data Collection Methods

Data were collected using interviews, direct counts, and focus group discussions (FGDs). Interviews provided local knowledge and contextual understanding of species richness and abundance. FGDs involved key informants, including forest reserve managers, plant specialists, game rangers, and community members.

Forest reserve managers, plant specialists, and game rangers were interviewed due to their extensive experience and continuous presence within the reserves. Their insights offered valuable information on species distribution trends, biodiversity changes over time, and the effects of conservation measures. Interviews focused on observed changes in plant and animal populations, threats to biodiversity, and management practices affecting species abundance.

Community members living near the reserves were also interviewed to incorporate traditional ecological knowledge and local observations. These individuals often rely on forest resources and have long-term interactions with the landscape, making their perspectives critical to understanding local biodiversity patterns.

Plant species richness and abundance were assessed using direct counts. Individual plants were physically identified and enumerated within defined sampling areas. The number of individuals per species was recorded to determine abundance, while the total number of species was used to estimate species richness. This standardized and replicable method allowed comparisons across reserves and enabled detection of spatial patterns in plant distribution and diversity.

2.7 Data Collection Instruments

Questionnaires and interview guides were used as data collection instruments. For plant and animal biodiversity, questionnaires were administered to wildlife managers and conservation officers to document species presence and abundance. Interview guides were used to gather information from local residents about wildlife population changes over time, community-led conservation practices, and traditional knowledge on sustainable land and resource use.

2.8 Data Analysis Techniques

Qualitative data were analyzed thematically by grouping similar responses into categories and identifying recurring ideas, topics, and patterns. Quantitative data were analyzed using Microsoft Excel software. The Shannon-Wiener Index (Shannon Diversity Index) was used to assess biodiversity status. For each species, the proportion of the total number of individuals was calculated by dividing the number of individuals of a species by the total number of individuals in the community. The natural logarithm of each proportion was computed, multiplied by the proportion, and summed across all species. The sum was then multiplied by -1 to obtain the Shannon Diversity Index. The resulting index values were used to compare species richness and evenness across the three study sites.

3. Results and Discussion

3.1 Plant Species Richness and Abundance

Species richness and abundance in each protected area were determined by summing the number of individuals of each species across all plots in the selected reserves. The study revealed considerable variation in species richness among the protected areas.

As shown in Figure 2, high species richness and abundance were observed among trees of the Fabaceae family in Mzuzu Botanic Garden (Northern Malawi), including *Brachystegia speciformis* (Msasa), *Pterocarpus angolensis* (Mlombwa), *Dalbergia nitidula* (Mtankanyerere), *Azelia quanzensis* (Mpapa), and *Pericopsis angolensis* (Muwanga trees). Trees of the Fabaceae family are commonly found in tropical and subtropical regions and provide habitat

and food for various animals, including birds and insects [55]. Their abundance in Mzuzu Botanic Garden can be attributed to their native status, which allows them to thrive under local climate and soil conditions without requiring extensive care or resources. Moreover, Mzuzu Botanic Garden prioritises the conservation of native species. By maintaining and propagating Fabaceae trees such as Mpapa, the garden supports local ecosystem stability and promotes environmental sustainability. Conversely, lower species richness and abundance were recorded for other tree families, such as Phyllanthaceae and Myrtaceae. For instance, *Uapaca kirkiana* (Masuku) of the Phyllanthaceae family was found in minimal quantities. This scarcity may be due to its preference for well-drained soils and areas with distinct dry seasons, conditions that are not consistently present in the Mzuzu Botanic Garden environment [56]. Additionally, the garden’s management focuses on conserving endangered species, which reduces emphasis on *Uapaca kirkiana*. Propagation of this species is also challenging, particularly in a controlled garden setting [56].

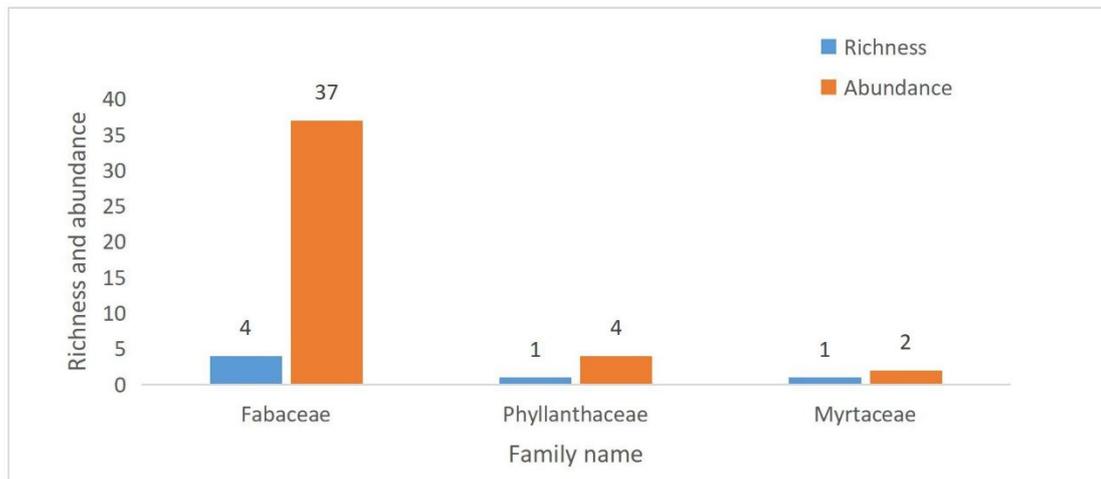


Fig. 2 Plant Species richness and abundance in Mzuzu botanic garden

Figure 3 shows that there is high species richness and abundance of Fabaceae trees, such as *Azelia quanzensis* (Mpapa) and *Brachystegia speciformis* (Msasa), in Mulanje Mountain, which provides an ideal habitat for these species. The soil and climate conditions are highly conducive to their growth [57]. However, some Fabaceae species, such as *Pterocarpus angolensis* (Mlombwa), were observed in minimal quantities despite being native to the region. The presence of invasive plant species, including *Rubus ellipticus* (Himalayan raspberry) and *Pinus patula* (Mexican pine), negatively impacts the growth and abundance of native species like *Pterocarpus angolensis*. These invasive species compete with native plants for essential resources such as light, water, and nutrients, making it difficult for native species to thrive [58]. Additionally, *Pterocarpus angolensis* (Mlombwa) is vulnerable to deforestation due to its high timber value.

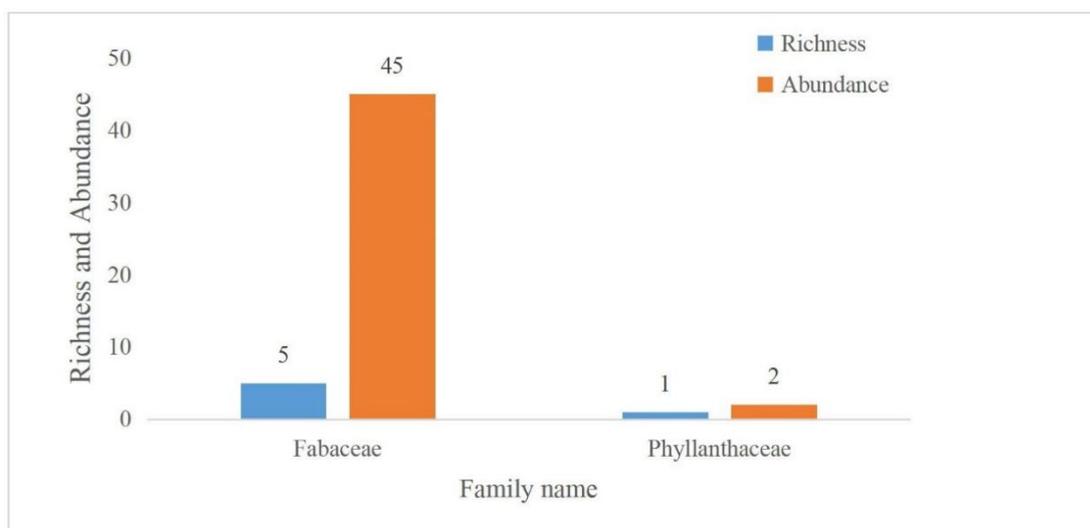


Fig. 3 Plant species richness and abundance in Mulanje Forest reserve

Figure 4 shows low species richness but high abundance of the tree climber *Ximenia caffra* (Njikha) of the Ximeniaceae family. The study also revealed relatively low but even species richness, abundance, and distribution of trees from other families, including Fabaceae, Combretaceae, and Malvaceae, in Lilongwe Nature Sanctuary. Previous studies [59–61] indicate that species such as *Albizia harveyi* (Mpalankhanga), *Pterocarpus angolensis* (Mlombwa) (Fabaceae), *Follinectera valencia* (Mpakasa) (Malvaceae), and *Combretum molle* and *Combretum collinum* (Combretaceae) have specific habitat requirements that may not be fully met within the sanctuary's environmental conditions. For instance, *Albizia harveyi* (Mpalankhanga) prefers riparian zones with stable moisture levels [59], while *Follinectera valencia* (Mpakasa) thrives in shaded, moist areas, which may be limited in the sanctuary due to environmental disturbances [60]. Similarly, *Pterocarpus angolensis* (Mlombwa) requires well-drained soils in lowland forests, and its distribution is constrained by land use changes and forest disturbances [61].

Consequently, these tree species are not abundant in Lilongwe Nature Sanctuary, as their ecological requirements are inadequately supported. Environmental disturbances, primarily due to urban expansion and infrastructure development, have further contributed to their decline [60]. Across the three study sites (Figures 2, 3, and 4), there is a concerning decline of *Pterocarpus angolensis* (Mlombwa), a species listed as vulnerable on the IUCN Red List, despite ongoing conservation efforts globally and within Malawi [2]. Its high timber value has led to increased illegal selective harvesting, posing a significant threat to the long-term survival of the species in the country's protected areas.

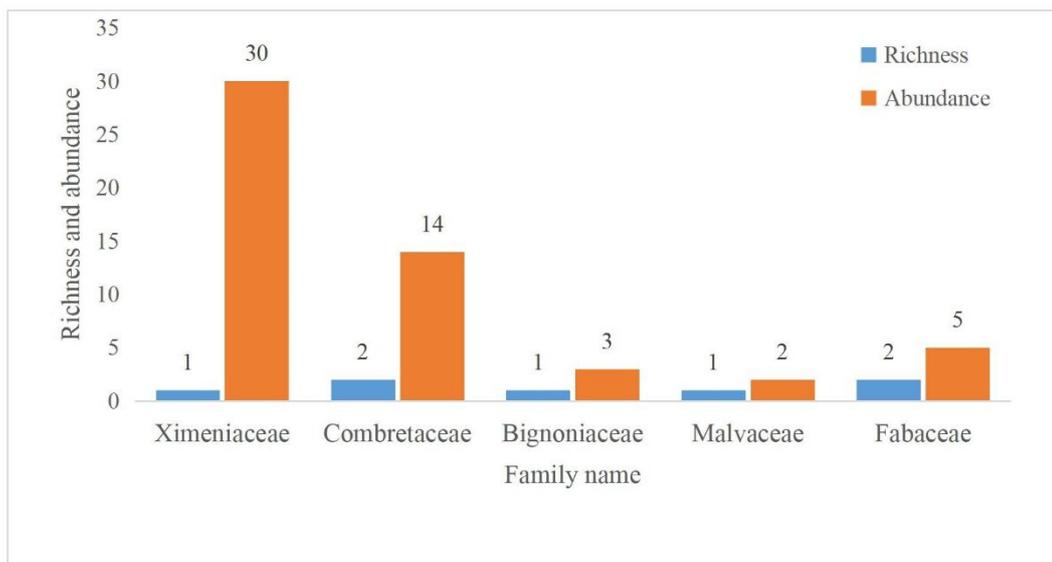


Fig. 4 Plant species richness and abundance in Lilongwe Nature Sanctuary

3.2 Comparison of Species Diversity in the Three Protected Areas

Lilongwe Nature Sanctuary, covering an area of 137 hectares and located in central part of Malawi (Fig 1), exhibited lower species evenness and diversity, with a Shannon-Wiener diversity index of 1.18 (Table 1). The vegetation is predominantly dominated by small *Ximenia caffra* (Njikha) trees, which create a dense understory. However, these small shrubs hinder the germination of larger tree species, thereby reducing overall species diversity and abundance. In addition, the sanctuary is heavily infested with *Lantana camara* (Nakasonde), an invasive alien species (IAS) that negatively affects plant nutrition. Similarly, a study in Uganda [62] reported that *Lantana camara* invasion reduced vegetation diversity through chemical interference with native plants, caused by phenolic compounds present in the leaf litter. The ability of *Lantana camara* (Nakasonde) to alter soil properties—such as increasing pH, phosphorus, nitrogen, manganese, iron, and total organic carbon [63]—further limits the growth and health of native plant species [64].

Table 1 Shannon-Wiener index for Lilongwe natural sanctuary

Plant species	Local name	Abundance	Pi	Ln pi	(pi)(lnpi)
<i>Ximenia caffra</i>	Njinkha	30	0.6	-0.51	-0.31
<i>Albizia Harvey</i>	Mpalankhanga	1	0.02	-3.91	-0.08
<i>Combretum molle</i>	Kalama	2	0.04	-3.22	-0.13
<i>Combretum collinam</i>	Kalama	12	0.24	-1.43	-0.34
<i>Cordia abyssinica</i>	Msewa	3	0.06	-2.81	-0.17
<i>Follinectera Valencia</i>	Mpakasa	1	0.02	-3.91	-0.08
<i>Pterocarpus angolensis</i>	Mlombwa	1	0.02	-3.91	-0.08
Total		50	1		-1.18
					H=1.18

The Mzuzu Botanic Garden spans over 575 hectares and is located in the northern part of Malawi (Fig. 1). The study revealed that the garden exhibits relatively low species diversity and evenness, with a Shannon-Wiener diversity index of 1.52 (Table 2).

Table 2 Shannon-Wiener index for Mzuzu botanic garden

Plant species	Local name	Abundance	Pi	Ln pi	(pi)(lnpi)
<i>Afzelia quanzensis</i>	Mpapa	16	0.37	0.99	-0.37
<i>Pericopsis angolensis</i>	Muwanga	14	0.33	1.11	-0.37
<i>Dalbergia nitidula</i>	Mtankanyerere	4	0.09	2.42	-0.22
<i>Uapaka kirkiana</i>	Masuku	4	0.09	2.42	-0.22
<i>Syzigium cordatum</i>	Katope	2	0.05	2.99	-0.15
<i>Pterocarpus angolensis</i>	Mlombwa	3	0.07	2.65	-0.19
Total		43	1		-1.52
					H=1.52

Mulanje Forest Reserve located in the southern part of Malawi (Fig 1), was established in 1927, and covers 56,317 hectares [65]. The plant species in the reserve exhibited relatively low diversity, with a Shannon-Wiener index of 1.13 (Table 3). *Afzelia quanzensis* (Mpapa) dominated most of the area. These findings are consistent with those reported by Foque and Mphamba (2019) [66], who noted that the western, northern, and eastern foothills of Mulanje Mountain are extensively covered by *Brachystegia* species (Miombo), while *Widdringtonia whytei* (Mulanje cedar) is restricted to a few high-altitude locations.

Furthermore, Tables 1, 2, and 3 show that Lilongwe, Mzuzu, and Mulanje had Shannon diversity indices of 1.18, 1.52, and 1.13, respectively, indicating ecosystems with low diversity and uneven species distribution. Among the three sites, Mzuzu Botanic Garden has the largest area and the most diverse ecosystem (index 1.52), whereas Mulanje and Lilongwe exhibited lower diversity, with index values of 1.13 and 1.18, respectively.

Table 3 Shannon-Wiener index for Mulanje forest reserve

Plant species	Local name	Abundance	Pi	Lnpi	(pi)(Lnpi)
<i>Pterocarpus angolensis</i>	Mlombwa	2	0.04	-3.22	-0.14
<i>Afzelia quanzensis</i>	Mpapa	32	0.68	-0.39	-0.26
<i>Uapaka kirkiana</i>	Masuku	2	0.04	-3.22	-0.14
<i>Afzelia quanzensis</i>	Msambafumu	4	0.09	-2.41	-0.20
<i>Acacia nigrescens</i>	Mkunkhu	3	0.06	-2.81	-0.18
<i>Erythrina abyssinica</i>	Muwale	4	0.09	-2.41	-0.21
Total		47	1		-1.13
					H=1.13

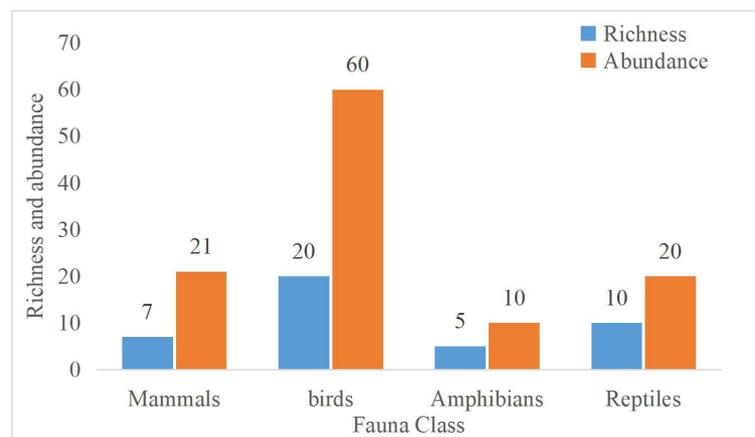
3.3 Animal Species Richness and Abundance

The study revealed variation in animal species richness across the protected areas, influenced by regional climatic and edaphic factors. Overall, birds exhibited the highest species richness and abundance, while amphibians were the least represented in all three reserves, as shown in Figures 5, 6, and 7.

In Lilongwe Natural Sanctuary, a notable decline in species richness and abundance was observed (Fig. 5). Birds had the largest presence in the sanctuary, whereas mammals, amphibians, and reptiles were sparsely distributed. Several studies have demonstrated that animal species are closely linked to plant communities [67–69]. Tree species richness, density, canopy cover, and height have been shown to correlate positively with animal richness and abundance. These findings correspond to the situation in Lilongwe Natural Sanctuary, where vegetation cover has been significantly reduced due to urban expansion, including construction of shops, offices, and roads, which has decreased the sanctuary's area.

In addition, noise from heavy machinery used to expand Kenyatta Drive into a six-lane road has led to the migration of certain animals, including hyenas, bush pigs, and antelopes, to other areas such as the State House residence and Malingunde Forest Reserve, as reported by the Ministry of Transport [70]. Similar impacts of road construction on wildlife have been documented in Tanzania and Brazil. Laurence in 2004, reported that road construction fragments natural habitats, disrupts migration routes, and increases human-wildlife conflicts. For instance, roads through the Serengeti National Park in Tanzania have fragmented habitats for large herbivores such as wildebeest and zebra, while Amazonian roads have disrupted habitats for jaguars and primates, contributing to population declines through increased poaching, traffic accidents, and habitat loss [71].

The study also found that seasonal decreases in water levels and drying of the Lingadzi River during hot periods negatively affect amphibians and reptiles in the sanctuary. Beche, McElravy, and Resh (2016) reported that seasonal river drying in California, influenced by climatic conditions, significantly affects the biodiversity and community structure of aquatic and semi-aquatic species. These dry periods result in shifts in species composition and abundance, with some species adapting to fluctuating conditions while others decline [72].

**Fig. 5** Animal species richness and abundance for Lilongwe Nature Sanctuary

In Mzuzu Botanic Garden, a notable decline in species richness and abundance was also observed (Fig. 6). Birds had the highest presence compared to other animal groups. Amphibians and reptiles, however, were declining in abundance, primarily due to temperature fluctuations during the cold and hot seasons. Gomez-Mestre et al. (United Kingdom) [73] highlighted that ectotherms, such as amphibians and reptiles, are highly sensitive to temperature changes, which directly impact their survival and reproductive rates. In cold climates, these species are particularly vulnerable, as they cannot internally regulate their body temperature, limiting their ability to thrive.

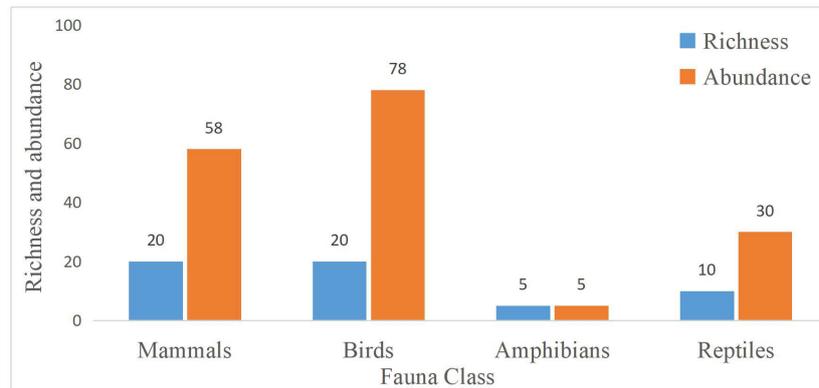


Fig. 6 Animal species richness and abundance for Mzuzu Botanic Garden

In Mulanje Forest Reserve, a significant decline in species richness and abundance was also observed (Fig. 7). As in Lilongwe Sanctuary and Mzuzu Botanic Garden, birds had the highest occupancy compared to other animal groups. According to Avibase, Mulanje Forest Reserve hosts around 268 bird species, including seven threatened species such as Verreaux's Eagle, African White-backed Vulture, Mulanje Chameleon Chat including others and two newly introduced species (Yellow-throated Bush Sparrow and Gymnoris) [74]. The abundance of bird species is attributed to the large forest area, which provides ample food and clean water, as well as the reserve's mild climate with moderate temperatures and rainfall that create favourable conditions for birds to thrive. In contrast, populations of other animals, including mammals, reptiles, and amphibians, are declining, largely due to extreme temperatures. Reptiles and amphibians are ectothermic and depend on external sources of heat, which limits their survival in colder conditions [74].

A similar pattern has been observed in other regions. For example, Stouffer and co-authors in 2013, conducted a study in the Amazon Rainforest, South America, and reported that larger tracts of tropical forest support higher bird diversity due to abundant food resources, such as fruits and insects, and access to freshwater from rivers and streams [75]. Forest size was found to directly correlate with bird diversity, as larger areas provide more habitats and food sources essential for sustaining diverse bird populations. Similarly, in Southeast Asia (Malaysia), Sodhi et al. [76] demonstrated that large forests with plentiful food and water sources support higher bird richness by providing a variety of habitats, from tree canopies to forest floors, which cater to different species. Rivers and streams further enhance bird diversity by supplying reliable drinking water [76].

Across Lilongwe Natural Sanctuary, Mzuzu Botanic Garden, and Mulanje Forest Reserve, a striking trend emerges: bird species exhibit high richness and abundance, whereas mammal, reptile, and amphibian populations are declining (Figs. 5, 6, and 7). Beyond natural environmental conditions, anthropogenic pressures such as habitat loss and fragmentation, human-wildlife conflict, climate change, and environmental degradation also contribute to the decline of these animal groups across the protected areas.

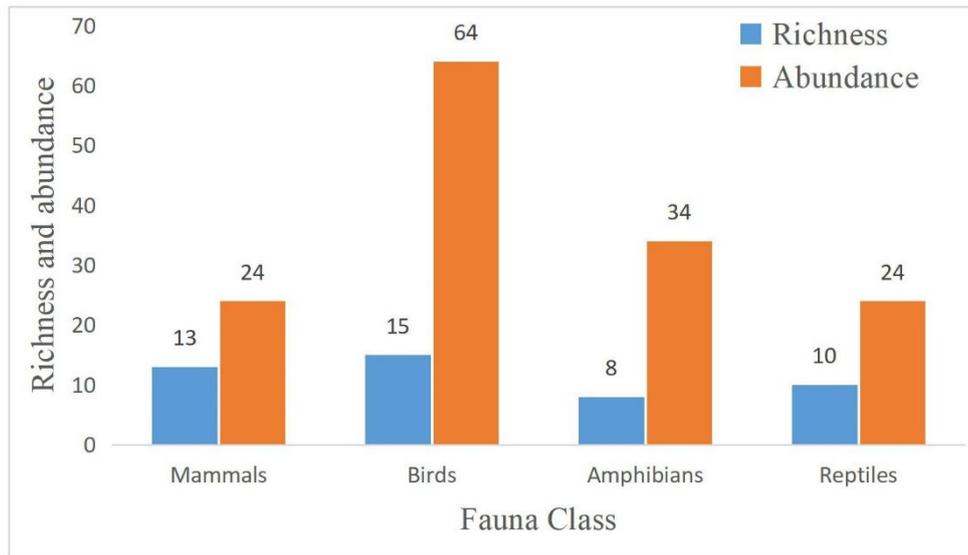


Fig. 7 Animal species richness and abundance for Mulanje Forest Reserve.

3.4 Impact of Anthropogenic Activities on Species Richness and Abundance

Table 4 illustrates the influence of human activities on the existence of animal species in the protected areas. Across the sites, it was observed that populations of various animal species have declined, and some have become locally extinct. Most respondents reported that anthropogenic activities have caused significant harm to biodiversity and ecosystem health within the protected areas.

Deforestation has contributed to the decline of important plant species, such as Mulanje Cedar (*Widdringtonia whytei*) and *Pterocarpus angolensis* (Mlombwa). Expansion of agricultural land and urbanization has resulted in encroachment into natural reserves, such as Mulanje Mountain Forest Reserve, thereby reducing the area available for plant and animal species and consequently affecting their abundance and richness. Respondents also noted that invasive species, such as *Lantana camara* (Nakasonde), introduced primarily through seed dispersal, have contributed to the decline of native plant species that serve as food for herbivorous wildlife.

A study by Chikuni et al. [77] on deforestation in the Mulanje Mountain area confirmed that illegal logging has led to the loss of key species like Mulanje Cedar and *Pterocarpus angolensis*, significantly reducing regional biodiversity and negatively impacting ecosystem function. Similarly, Mvula et al. [78] highlighted that poaching in Lilongwe Wildlife Sanctuary has caused substantial declines in populations of warthogs and antelopes, hence disrupting ecological balance and diminishing overall biodiversity.

In Mzuzu Botanic Garden, anthropogenic pressures were higher before 1989 when the reserve was managed by the Mzuzu City Council. Following the establishment of the Natural Herbarium and Botanic Garden of Malawi in 1989, habitat restoration efforts substantially reduced these pressures, leading to increases in species richness and abundance. Overall, forest clearance destroys habitats and disproportionately affects native and endemic species, leading to a decline in biodiversity [79]. Furthermore, the introduction of invasive species results in biotic homogenization, whereby communities become dominated by a few resilient species while native species decline.

These findings are consistent with studies on Miombo woodlands in Malawi, where species diversity and evenness were higher in undisturbed plots compared to disturbed areas [80]. Selective logging in disturbed areas was identified as a major driver of reduced species richness and abundance. In Mulanje Forest Reserve, anthropogenic activities such as hunting for bush meat, poaching for ivory (elephants), and harvesting other animal parts (e.g., hyena claws) have led to declines and local extinctions of elephants, warthogs, antelopes, hyenas, and monkeys. Increasing human populations have also escalated demand for land, water, and food, contributing further to habitat destruction and fragmentation.

A survey by Mabaso and co-authors in 2014, reported 63,747 standing mature Mulanje Cedar trees. A repeat survey in January 2017 recorded only seven remaining trees, and by February 2018, all had been removed, leaving zero mature Mulanje Cedars on Mulanje Mountain [81, 82]. In just over three years, tens of thousands of trees were illegally harvested for domestic and international trade. These statistics underscore the urgent need to protect Mulanje Mountain—a key biodiversity and tourism hotspot—and other natural reserves in Malawi. Implementing effective conservation strategies is critical to mitigating human impacts and preserving Malawi's unique biodiversity across all protected areas.

Table 4 Status of selected animals due to anthropogenic activities

Animal species	Status in different protected areas		
	Lilongwe nature sanctuary	Mzuzu botanic gardens	Mulanje forest reserve
Hyenas	Decreased	Decreased	Decreased
Warthogs	Extincted	Extincted	Decreased
Elephants	Extincted	Extincted	Extincted
Monkeys	Decreased	Decreased	Decreased
Antelopes	Decreased	Extincted	Decreased

3.5 Challenges Faced When Implementing Mitigation Measures to Biodiversity Loss

Most respondents reported that poor relationships between communities and forest reserve authorities significantly hinder community-based conservation efforts. This tension is often exacerbated by excessive use of force, including physical abuse, unnecessary restraints, verbal abuse, and unlawful arrests without proper justification. Lindhjem and Haug [83] demonstrated that overly strict enforcement of mitigation measures in human-wildlife conflicts can undermine relationships with local communities, reducing the effectiveness of conservation efforts.

Despite conservation measures, some community members continue to encroach protected areas to poach animals using dangerous weapons and firearms. The introduction of invasive species (IS) through seed dispersal also poses a challenge, as these species compete with native plants for sunlight, water, and nutrients, ultimately reducing the growth of important plant species that serve as food for wildlife. Similarly, Martin [84] reported that *Lantana camara* (Nakasonde) had a major impact on graminoids and forbs at Imire Ranch, Wedza District, Zimbabwe. In his study, herbaceous species abundance and diversity declined in areas invaded by *Lantana camara*, which releases phenolic acids, flavonoids, terpenes, and terpenoids that inhibit the growth of neighbouring plants [84].

Insufficient funding also limits the hiring of additional game rangers and the acquisition of equipment necessary to guard the reserves effectively. Furthermore, human-wildlife conflict hinders the relocation of animals to protected areas. A study by Jamal Mohammed [85] in the Sub-Saharan Africa region found that, in Ethiopia, Kenya, and Uganda, increased urban demand for food incentivised farmers to convert forests into agricultural land. Urbanization and expansion of transportation networks have also led to increased habitat fragmentation. These challenges are evident in Lilongwe Nature Sanctuary, where the construction of a six-lane Kenyatta Road caused habitat fragmentation, reduced reserve area, and prompted animal migration to areas such as Dzalanyama Forest.

3.6 Influence of Traditions and Culture on Conservation of Plant Species

Biodiversity in Malawi fulfils numerous socio-cultural functions. Spiritually, many Malawian ethnic groups believe in supernatural beings or ancestral spirits associated with graveyards or forested mountain areas. For example, the Mang'anja of Nsanje worship their ancestral spirit M'bona in Khuluvi Forest. The Chewa tribe's Gule wa Mkulu and the Ngoni tribe's Ingoma dance also incorporate regalia derived from plant and animal products [86].

In Mulanje, the Lhomwe, Yao, and Mang'anja people, despite having distinct cultural beliefs, share the conviction that spirits inhabit Mulanje Mountain and influence life on the mountain. Local lore suggests that well-prepared food can sometimes be found on the mountain, provided by the spirits, and it is advised that the finder should consume it alone. Certain trees on the mountain are believed to house spirits, and cutting these trees is thought to be forbidden; they are said to regenerate if removed. These beliefs have directly promoted the conservation of specific trees and forested areas, preserving plant species and abundance because local people are deterred from harvesting them.

Conversely, some cultural beliefs have inadvertently threatened forest reserves. For instance, Mulanje cedar has long been considered a species planted solely by divine intervention, discouraging communities from replanting it amidst continued illegal harvesting. Moreover, careless collection of plant parts, such as bark and roots for medicinal purposes, sometimes kills the plant. These challenges have compelled reserve management to restrict the harvesting of plant parts for medicinal use [87].

3.7 Conclusion and Recommendation

The three protected areas studied—Mzuzu Botanic Garden, Lilongwe Nature Sanctuary, and Mulanje Forest Reserve—possess rich biodiversity. However, factors such as deforestation, agricultural expansion, climate change, urbanization, and limited funding have led to a decline in species richness and abundance. In response, reserve managers have implemented a range of conservation measures, including day and night patrols to prevent encroachment, awareness campaigns and outreach programs to foster appreciation for nature, reforestation programs, and the establishment of woodlots to support sustainable use of resources. Fence and boundary construction has also contributed to reducing biodiversity loss. Nonetheless, poverty remains a major challenge to the effective implementation of these mitigation measures.

To strengthen biodiversity conservation, sustainable control measures should be adopted to eliminate *Lantana camara* (Nakasonde) from invaded areas and prevent its further spread, thereby improving the overall health of protected forest reserves. Increased government funding for wildlife and park management is crucial to support operations, including the installation of electrified fences around protected areas to reduce animal migration and human-wildlife conflict. Strengthening relationships between protected areas and surrounding communities will encourage communal stewardship of natural resources. In addition, civic education programs should be intensified to raise awareness about the value of plant and animal species, reduce human-wildlife conflict, and foster long-term conservation behaviours. These combined efforts by all stakeholders are essential to ensure the continued protection and restoration of Malawi's unique biodiversity.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** James Majamanda, Fred Goliath, Effiness Gwiriza, Watson Gondwe, Grace Gausi; **data collection:** Fred Goliath, Effiness Gwiriza, Watson Gondwe, Grace Gausi; **analysis and interpretation of results:** James Majamanda, Fred Goliath, Effiness Gwiriza, Watson Gondwe, Grace Gausi; **draft manuscript preparation:** James Majamanda. All authors including Pachalo Matandara reviewed the results and approved the final version of the manuscript.

References

- [1] Maclaurin, J., & Sterelny, K. (2008). *What is biodiversity?* University of Chicago Press.
- [2] International Union for Conservation of Nature (IUCN). (2020). *Guidelines for applying protected area management categories*. IUCN.
- [3] World Wildlife Fund. (2024). *Living Planet Report 2024: A comprehensive analysis of biodiversity and the health of the planet*. WWF.
- [4] Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, 115(25), 6506–6511. <https://doi.org/10.1073/pnas.1711842115>
- [5] Barnosky, A. D. (2014). Prehistoric and historic decline in mammal populations. *Proceedings of the National Academy of Sciences*, 111(17), 6474–6479.
- [6] Ramsar Convention Secretariat. (2025). *List of wetlands of international importance*. Ramsar Convention.
- [7] African Development Bank Group. (2020). *Why should biodiversity be Africa's top priority?* AfDB.
- [8] World Resources Institute. (2020). *Indigenous peoples and local communities: Key actors in the protection of natural resources*. WRI.
- [9] Wilson, E. O. (2023). *Biodiversity Foundation Malawi*. E.O. Wilson Foundation.
- [10] Environmental Affairs Department. (2006). *National biodiversity strategy and action plan*. Government of Malawi.
- [11] Muschick, M., & Salzburger, W. (2011). Convergent evolution within an adaptive radiation of cichlid fish. *BMC Evolutionary Biology*, 11, 314. <https://doi.org/10.1186/1471-2148-11-314>
- [12] Bezner Kerr, R., et al. (2025). Collaborative reforestation in Malawi supports agriculture and climate adaptation. *Cornell Chronicle*.

- [13] Lal, R. (2001). Soil degradation by erosion. *Land Degradation & Development*, 12(6), 519–539.
- [14] Kissui, B. M., et al. (2017). Conservation challenges and successes in Malawi's protected areas. *Conservation Biology*, 31(5), 1035–1046.
- [15] Dunham, K. M., et al. (2016). Conservation of large mammals in Malawi. *African Journal of Wildlife Conservation*, 22(1), 33–46.
- [16] Ngwira, A., et al. (2018). Climate change and biodiversity at Mount Mulanje, Malawi. *Environmental Monitoring and Assessment*, 190(5), 309.
- [17] Danish Hunters' Association. (2024). *Poaching crisis: Current situation and the path forward*. DHA Press.
- [18] Sodhi, N. S., et al. (2010). Biodiversity conservation in the era of global change. *Biodiversity and Conservation*, 19(7), 2335–2346.
- [19] Mora, C., et al. (2011). How many species are there on Earth and in the ocean? *PLoS Biology*, 9(8), e1001127. <https://doi.org/10.1371/journal.pbio.1001127>
- [20] Vitousek, P. M., et al. (1986). Human appropriation of the products of photosynthesis. *Bioscience*, 36(6), 368–373.
- [21] Lambin, E. F., & Meyfroidt, P. (2011). Global land use change and land scarcity. *Proceedings of the National Academy of Sciences*, 108(9), 3465–3472.
- [22] International Rhino Foundation. (2024). *Rhino population update*.
- [23] Harris, R. B., & Maclean, J. (2020). Recovery of the black rhinoceros in Zambia. *African Journal of Wildlife Research*, 50(1), 53–61.
- [24] Blignaut, J. N., & Jooste, A. (2013). Reintroducing black rhinos into Zambia. *African Journal of Wildlife Research*, 43(2), 149–156.
- [25] Bennett, E. L., et al. (2016). Rhino conservation strategies. *Conservation Biology*, 30(6), 1271–1281.
- [26] Chansa, W., et al. (2019). Wildlife conservation policies in Malawi. *African Journal of Conservation*, 13(2), 56–67.
- [27] Blake, S., et al. (2017). Decline of African elephants in Mozambique. *African Wildlife Conservation*, 29(4), 118–130.
- [28] Government of Mozambique. (2010). *National strategy and action plan for elephant conservation*
- [29] Masumi Gudka (2020). *Kenya National Biodiversity Threat Assessment*, International Union for Conservation of Nature
- [30] Department of National Parks and Wildlife (DNPW). (2021). *Elephant Distribution and Conservation in Malawi: Current Status and Threats*. Malawi Government Press.
- [31] United Nations Development Programme (UNDP). (2020). *Supporting Access to Genetic Resources and Fair Benefit Sharing: The Role of the Nagoya Protocol*. Retrieved from www.undp.org
- [32] Secretariat of the Convention on Biological Diversity. (2010). *Global Diversity Outlook 3*. Montreal, Canada: SCBD
- [33] United Nations Environment Programme (UNEP). (2012). *Global Environment Outlook 5*. Nairobi Kenya: UNEP
- [34] Miller, L., & Wright, S. (2019). NGOs and government collaboration for biodiversity conservation. *Conservation Journal*, 45(2), 78–92.
- [35] Environmental Affairs Department. (1994). *State of Environment in Malawi*.
- [36] Government of Malawi (2010), *Malawi State of Environment and Outlook Report*, Environmental Affairs Department.
- [37] Mojeremane, W., & Lumbile, A. U. (2016). A Review of *Pterocarpus angolensis* DC. (Mukwa) an Important and Threatened Timber Species of the Miombo Woodlands. *Research Journal of Forestry*, 10(1), 8–14.
- [38] Malawi Government. (2007). *Forestry Act (No. 4 of 1997) and Forest Regulations (1999)*. Lilongwe: Ministry of Natural Resources, Energy and Mining.
- [39] Mozambique Government. (2008). *Forest and Wildlife Law (Law No. 10/2002) and Regulations (Decree No. 12/2003)*. Maputo: Ministry of Agriculture and Rural Development.
- [40] Zambia Government. (2014). *Forests Act (No. 13 of 1999) and Forest Regulations (Statutory Instrument No. 94 of 2000)*. Lusaka: Ministry of Lands, Natural Resources and Environmental Protection.

- [41] Government of Malawi (2014); *Fifth National Report to the Convention on Biological Diversity*, Environmental Affairs Department.
- [42] Coen, T., Mamun, A., Ringler, C., Nkonya, E. M., Velyvis, K., Xie, H., ... & Sloan, M. (2018). *Evaluation design for the environmental and natural resource management project in Malawi*. Washington, DC: Mathematical Policy Research.
- [43] Malawi Government. (1998). Local Government Act, 1998. Malawi Government: Malawi
- [44] Dobson, T. (1997). Radical restructuring of environmental policy to preserve biodiversity in southern Africa: Malawi at the crossroads. *J. Nat. Resources & Envntl. L.*, 13, 149.
- [45] Coutts, C., Holmes, T., & Jackson, A. (2019). Forestry Conservation activities, and ecosystem services in the remote Misuku Hills of Malawi. *Forests*, 10(12)1056.
- [46] Muganda, P. K. (2012). The impact of environmental legal frameworks and collaborations on operations of environmental NGOs in Kenya (Doctoral dissertation, University of Nairobi, Kenya).
- [47] Williams, B. K., Nichols, J. D., & Conroy, M. J. (2002). *Analysis and Management of Animal Populations: Modelling, Estimation, and Decision Making*. Academic Press.
- [48] Barton, D. N., et al. (2013). The effect of land use on biodiversity: A case study in a rural landscape. *Journal of Environmental Management*, 118, 80-89.
- [49] Lilongwe, Malawi Population 2024. *World Population Review*. Retrieved November 10, 2024, from <https://worldpopulationreview.com/cities/malawi/lilongwe>
- [50] World Population Review. (2024). *Population of Mzuzu and Mulanje, Malawi*. Retrieved from worldpopulationreview.com
- [51] Sayer, J. A., et al. (1992). The role of protected areas in tropical forest conservation. *Global Ecology and Biogeography Letters*, 2(1), 1-7.
- [52] Balmford, A., et al. (2002). Conservation conflicts across Africa. *Science*, 291(5511), 2616-2619
- [53] Buckland, S. T., et al. (2015). *Estimating animal abundance: Closed populations*. Wiley Online Library.
- [54] Danielsen, F., et al. (2005). The Asian tiger mosquito: Understanding local ecological knowledge in biodiversity conservation. *Global Environmental Change*, 15(4), 403-413.
- [55] Smith, A. B., & Johnson, C. D. (2021). Climatic conditions and growth patterns of *Brachystegia speciformis* in Southern Africa. *Tropical Ecology*, 58(4), 789-802.
- [56] Maliro, M. F. A., & Kwapata, M. B. (2000). Apomictic embryo development and survival in *Uapaca kirkiana* under in vitro and in vivo seed germination. *Scientia Horticulturae*, 83(2), 139-147.
- [57] Palgrave, C. K. (1983). *Trees of Southern Africa (2nd ed.)*. Cape Town, South Africa: Struik Publishers.
- [58] Kasaga, K. (2022). Impact of *Lantana camara* on native vegetation structure and diversity of Kakiika (Unpublished dissertation). Makerere University College of Natural Sciences, Mbarara, Uganda.
- [59] Chirwa, P. W., & Kadzandira, J. M. (2011). Distribution and ecological requirements of *Albizia harveyi* in Malawi. *African Journal of Ecology*, 49(1), 35-42.
- [60] Smith, A. B. (2014). Habitat preferences of *Follinectera valencia* and its sensitivity to forest disturbances. *Journal of Tropical Forest Ecology*, 56(2), 128-134.
- [61] Kamwendo, F. T., & Chilima, P. (2018). Ecological requirements and distribution of *Pericopsis angolensis* in Malawi. *African Journal of Forestry and Forest Products*, 6(3), 45-52.
- [62] Harminder, P. S., Daizy, R. B., Kuldip, S. D., Shalinder, K., Ravinder, K. K., & Anjana, N. (2014). Negative effect of litter of invasive weed *Lantana camara* on structure and composition of vegetation in the lower Siwalik Hills, northern India. *Environmental Monitoring and Assessment*, 186(6), 3379 – 3389
- [63] Subha, C. L., & Chandra, C. S. (2018). Impact, management and uses of *Lantana camara* – A noxious weed. *Bulletin of Environment, Pharmacology and Life Sciences*, 7(11), 170-180. <http://www.bepls.com>
- [64] Parveen, K. D., Ravinder, K. K., & Daizy, R. B. (2011). Impact of *Lantana camara* L. invasion on riparian vegetation of Nayar region in Garhwal Himalayas (Uttarakhand, India). *Journal of Ecology and the Natural Environment*, 3(1), 11-22. <http://www.academicjournals.org/jene>
- [65] Government of Malawi. (2006). *National Biodiversity Strategy and Action Plan*. Environmental Affairs Department.
- [66] Foquet, R., & Mphamba, S. (2019). *Biodiversity Express Survey: Mount Mulanje and Malawi Hills*. Biodiversity Inventory for Conservation. <https://doi.org/10.13140/RG.2.2.21623.16807>

- [67] Cody, M. L. (1983). Bird diversity and density in South African forests. *Oecologia*, 59, 201-215.
- [68] Hurlbert, A. H. (2004). Species-energy relationships and habitat complexity in bird communities. *Ecology Letters*, 7, 714-720.
- [69] Wijesinghe, M. R., & Brooke, M. de L. (2005). Impact of habitat disturbance on the distribution of endemic species of small mammals and birds in a tropical rain forest in Sri Lanka. *Journal of Tropical Ecology*, 21, 661-668.
- [70] Ministry of Transport. (2021, August 31). *Reconstruction of Kenyatta Drive into a six-lane road*. <https://transport.gov.mw/index.php/resource-centre/media/top-news/91-posts/134-reconstruction-of-kenyatta-drive-into-six-lane-road>
- [71] Laurance, W. F. (2004). Roads to ruin? *Nature*, 427(6975), 129-131. <https://doi.org/10.1038/427129a>
- [72] Beche, L. A., McElravy, E. P., & Resh, V. H. (2006). Long-term seasonal variation in the biological traits of benthic macro-invertebrates in two Mediterranean-climate streams in California, U.S.A. *Freshwater Biology*, 51(1), 56-69. <https://doi.org/10.1111/j.1365-2427.2005.01474.x>
- [73] Gomez-Mestre, I., et al. (2013). The role of temperature in shaping the ecology and distribution of amphibians and reptiles in cold climates. *Journal of Zoology*, 291(2), 113-121. <https://doi.org/10.1111/jzo.12019>
- [74] Avibase. (2021). *Checklist of birds of Mulanje Mountain Forest, Malawi*. <https://avibase.bsc-eoc.org>
- [75] Stouffer, P. C., et al. (2013). The role of forest size and structure in maintaining bird diversity in the Amazon Rainforest. *Journal of Tropical Ecology*, 29(4), 289-300. <https://doi.org/10.1017/S0266467413000220>
- [76] Sodhi, N. S., et al. (2016). The importance of forest area and water sources for bird diversity in Southeast Asia. *Global Ecology and Biodiversity*, 25(10), 1340-1348. <https://doi.org/10.1111/geb.12512>
- [77] Chikuni, A. F., et al. (2014). The impact of deforestation on plant diversity in Mulanje Mountain, Malawi. *African Journal of Environmental Science and Technology*, 8(11), 735-743. <https://doi.org/10.5897/AJEST2014.1733>
- [78] Mvula, P. H., et al. (2016). The effects of poaching on mammalian species populations in the Lilongwe Wildlife Sanctuary, Malawi. *Journal of Wildlife Management*, 80(5), 845-852. <https://doi.org/10.1002/jwmg.106>
- [79] Adeoye, N. O., & Ayeni, B. (2011). Assessment of deforestation, biodiversity loss and the associated factors: Case study of Ekiti, South-western Nigeria. *GeoJournal*, 76(3), 229-243.
- [80] Yamashina, C., Hara, M., & Fugita, T. (2021). The effects of human disturbance on the species composition, diversity and functional diversity of Miombo woodland. *African Journal of Ecology*, 59, 216-224.
- [81] Mabaso, M. M., Kambewa, D., & Chirwa, P. W. (2018). Decline of Mulanje Cedar (*Widdringtonia whitei*) on Mulanje Mountain, Malawi: Population structure and mortality patterns. *Forest Ecology and Management*, 427, 70-78. <https://doi.org/10.1016/j.foreco.2018.05.015>
- [82] Bayliss, J., Makungwa, S., Hecht, J., Nangoma, D., & Bruessow, C. (2007). Saving the island in the sky: The plight of the Mount Mulanje cedar *Widdringtonia*. *Oryx*, 41, 64-69.
- [83] Lindhjem, H., & Haug, R. (2015). Human-wildlife conflicts and conservation: The need for inclusive management strategies in protected areas. *Journal of Environmental Management*, 56(3), 492-506.
- [84] Martin, Z. (2014). Impact of *Lantana camara* invasion on a cattle/wildlife ranch: A case of Imire Ranch, Wedza district, Zimbabwe (Unpublished thesis). University of Zimbabwe, Faculty of Sciences.
- [85] Jemal, M. A. (2020). Challenges in implementing biodiversity policy in Sub Saharan Africa region. *American Journal of Biological and Environmental Statistics*, 6(2). <https://doi.org/10.11648/j.ajbes.20200602.12>
- [86] Chavula, G. S. (2012). The role of traditional dance in the cultural identity of the Ngoni people of Malawi. *Journal of African Cultural Studies*, 24(2), 177-188.
- [87] Kalinda, T. H., & Chirwa, P. W. (2004). Medicinal plant use and its conservation in Malawi: A review. *Southern African Journal of Botany*, 70(4), 438-445. *Online Magazine Article*