The effects of anthropogenic disturbances on vegetation, birds, and nearby communities in selected Southern Mistbelt Forests in South Africa

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ABSTRACT

Globally, forests are threatened by several disturbance factors. Most of these include anthropogenic activities such as deforestation, land use, agricultural conversion, and fragmentation, driven by poverty and rapid population expansion. These disturbances have a considerable impact on forest structure and composition. In eastern South Africa, most rural communities are located near natural forest patches and, if not, are within travelling distance, which allows for unlimited access to forest resources. Overexploitation and harvesting are common in these regions. Nevertheless, forests provide valuable ecosystem services to local communities, while they are also crucial for biodiversity as they host most species, regardless of the small space they take up on Earth. Therefore, understanding the trends of disturbance and future implications is necessary. We explored the benefits and costs of mistbelt forest disturbance to the nearby communities and biodiversity. We compared lower, medium, and highly disturbed mistbelt forests in three different areas in terms of (1) bird species diversity, forest structural complexity and heterogeneity, and (2) the impacts, values, and perspectives of the nearby communities.

Firstly, we investigated the response of bird taxonomic and functional diversity to local and landscape characteristics. Bird species were sampled using fixed radius point counts at a distance of 200 m apart. The bird functional indices were quantified using the functional richness and functional evenness. The overall results showed a positive response of functional richness and evenness to structural complexity and heterogeneity. The categorical disturbance had a negative influence on the functional richness and evenness of the bird community, including the specialists and generalist bird species. However, we found that the functional richness and evenness in highly disturbed patches increased compared with medium disturbed patches. The results demonstrated

the importance of microhabitat covariates in promoting species diversity and conservation of endangered and vulnerable species. Moreover, monitoring of recovering forest patches is crucial given their possible future role in biodiversity conservation.

Secondly, we conducted a total of 360 interviews in seven villages/communities situated near indigenous forest patches using the questionnaires between October 2023 and January 2024. The overall results indicated that local community members benefit from forest resources such as firewood and traditional medicine. They use these resources to build houses, and fences, and generate sales. Furthermore, during the dry season, the forests become primarily important for foraging for their livestock. This prevents the use of expensive supplements to supplement their livestock. Therefore, human-nature interactions are an important step in balancing ecosystem services and conservation. In addition, forest ecosystems are crucial for the provision of ecosystem services for biodiversity and human livelihood. The proper management and conservation of the Mistbelt Forests is recommended for a long-term supply of resources and biodiversity conservation.

PREFACE

The data described in this thesis were collected in the Southern Mistbelt Forests in southern KwaZulu-Natal, Republic of South Africa, from September 2023 to July 2024. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T Downs and Dr Mfundo ST Maseko.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

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Siboniso Magoso

January 2025

I certify that the above statement is correct, and as the candidate's supervisor, I have approved this thesis for submission.

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Prof Colleen T Downs

Supervisor

January 2025

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DECLARATION 1 - PLAGIARISM

I, Siboniso Magoso, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
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DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

PUBLICATION 1- Formatted for *South African Journal of Botany*

Effects of anthropogenic activities on indigenous forests in Africa: A systematic review

S Magoso, MST Maeko & CT Downs

Author contributions:

SM conceived the paper with CTD and MSTM. SM collected and analysed data, and wrote the paper. CTD and MSTM contributed valuable comments to the manuscript.

PUBLICATION 2- Formatted for *Forest Ecology and Management*

Response of bird taxonomic and functional diversity to forest local and landscape characteristics in selected Southern Mistbelt Forests in KwaZulu-Natal, South Africa

S Magoso, MST Maseko, N Bitani & CT Downs

Author contributions:

SM conceived the paper with CTD and MSTM. SM collected and analysed data, and wrote the paper. CTD, NB and MSTM contributed valuable comments to the manuscript.

PUBLICATION 3- Submitted to *Trees, Forests and People*

Perceptions of the importance, value, and role of Southern Mistbelt Forests held by nearby communities in KwaZulu-Natal, South Africa

S Magoso, L Buthelezi, MST Maseko & CT Downs

Author contributions:

SM conceived the paper with CTD and MSTM. SM collected and analysed data, and wrote the paper. CTD and MSTM contributed valuable comments to the manuscript.

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Siboniso Magoso

January 2025

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Globally, forest logging is an ongoing crisis threatening biodiversity, especially in Africa (Adie et al., 2013; Brodie et al., 2015; Aleman et al., 2018; Armenteras et al., 2023; Mujetahid et al., 2023). The increase in the human population has resulted in various living demands. This constitutes food security, space, and employment (Ehlers Smith et al., 2019; Kimengsi et al., 2020). The exponential growth of the human population promotes forest exposure to disturbances as a result of exploitation and harvesting (Laurance et al., 2008; Gumede et al., 2020; Leaver and Cherry, 2020). This results in habitat loss and fragmentation which negatively affect forest biodiversity (Fisher, 2004; Constant and Taylor, 2020; Ngcobo et al., 2022). In South Africa, more than 250 ha of forests were lost in the past 73 years as a result of habitat transformation and other anthropogenic activities (Shackleton et al., 2007; Lawes et al., 2007; Ehlers Smith et al., 2019; Deere et al., 2019; Leaver and Cherry, 2020). Other commonly cited anthropogenic activities that pose a major threat to biodiversity are deforestation, fragmentation, agricultural conversion, logging, etc. (Menton et al., 2003; Makana and Thomas, 2006; Deere et al., 2019; Ehlers Smith et al., 2021; Mujedahit et al., 2023). In the context of agricultural activities, they have contributed about 78% to the conversion of tropical forests to commercial space, resulting in disconnected patches and fragmentation (Arroyo-Rodríguez et al., 2017; Deere et al., 2019; Ehlers Smith et al., 2019; Gumede et al., 2020). Connected habitats are important for the mobility of species, allowing for greater ecological processes such as seed dispersal, breeding, and pollination (Fahrig et al., 2003; Ehlers Smith et al., 2019; Sosibo et al., 2022a; Gumede et al., 2020; Paal et al., 2020).

Generally, the Southern Mistbelt Forests are naturally fragmented indigenous forests (Lawes et al., 2004; 2007b). These forests have experienced natural hazards which largely contributed to their fragmentation (King, 1941; Adie et al., 2013). This has also been documented in many localities globally, including Sulawesi Island, Indonesia (Mujetahid et al., 2023). These forests have also been previously overexploited for their products (King, 1941; Guertin, 2003; Hall et al., 2003; Robertson and Lawes, 2005; Njwaxu and Shackleton, 2019). As a result, the degradation of forests has been common in South Africa and other countries (King, 1941; Guertin, 2003; Armenteras et al., 2023). Many of the indigenous forest habitats have been dominated by invasive species because of the removal of native species by disturbances (Lawes et al., 2004; Brown and Gurevitch, 2004; Lewis et al., 2015). For example, in southeast Madagascar, the occurrence of *Psidium cattleianum* as an invasive species inhibited the establishment of native species (Brown and Gurevitch, 2004). Hence, the recolonisation of native species is prohibited or delayed for decades (Hall et al., 2003; Brown and Gurevitch, 2004; Lawes et al., 2004, 2007b; Rutten et al., 2015). Indigenous forests subjected to logging and severe disturbances are being dominated by thicket shade-intolerant understory (Lawes et al., 2004, 2007b; Njwaxu and Shackleton, 2019), as an indication of large pole harvested creating gaps in the canopy (Nomtshongwana 1999; Babaasa et al., 2004; Lawes et al., 2004, 2007b). These disturbances in the indigenous forests create difficulties for secondary succession and threaten forest ecosystems (Denslow and Hartshorn, 1994; Babaasa et al., 2004; Kleinschroth et al., 2013; Rutten et al., 2015).

1.2 Forests under threat in South Africa

In South Africa, the forest biome covers a relatively small portion of the land which is less than 0.56% of the total land area (King, 1941; Shackleton et al., 2007; Adie et al., 2013). Regardless, South African forests are among the most species-rich temperate forests in the world (Adie et al., 2013; Brodie et al., 2014; Deere et al., 2019). They provide valuable ecosystem services to biodiversity and human livelihood (Lewis et al., 2015; Codjo et al., 2017; Sosibo et al., 2022b). Historically, the Southern Mist Belt forests in the Eastern Cape and KwaZulu-Natal were naturally fragmented into smaller patches lying in a grassland landscape mosaic (Rycroft 1944; Mucina et al., 2006; Adie et al., 2013; Leaver and Cherry, 2020; Ngcobo et al., 2022). In recent years, this mosaic has developed increased human settlements and exotic tree plantations (Hall et al., 2003; Ngcobo et al., 2022). In KwaZulu-Natal Province, forests are located near the communities with about 75% of the communities located in close proximity with Indigenous Forest (Shackleton et al., 2007; Adie et al., 2013). Considering the short travel distance to reach the forest, harvesting forests for subsistence services is common (Shackleton et al., 2007; De Blas et al., 2011; Adie et al., 2013; Ofoegbu et al., 2017; Leaver et al., 2019a; Armenteras et al., 2023). The harvesting is mainly for building infrastructure, such as houses, fences, kraals, etc. (King, 1941; Nomtshongwana, 1999; Shackleton et al., 2007; Lawes et al., 2007; Sullivan et al., 2022). Forests in rural communities are essential in providing income and incentives (through small-scale commercial activities such as trading firewood for profit), contributing to consumption needs (Ofoegbu et al., 2017). Therefore, the dependency on forest resources for livelihood sustainability is prevalent in South Africa (Robertson and Lawes, 2005).

Although logging may benefit the human communities residing near the forest (Sosibo et al., 2022b), overexploitation may deteriorate the quality of the forest, leading to fragmentation over time (Lawes et al., 2004, 2007b; Cazzolla Gatti et al., 2015). This results in the local extinction of avian, mammalian, and plant communities (Ehlers Smith et al., 2017a; Sosibo et al., 2022a). While some species may explore different ecological niches (generalists), species' functional diversity is compromised because of decreasing specialist species (Leaver et al., 2019a, b; Bitani et al., 2023a, b). Generally, generalist species can persist in a variety of patches within the habitat (Ngcobo et al., 2022; Gumede et al., 2020, 2022), which makes them less susceptible to the destruction of forest habitat because of logging (Diaz et al., 2005; Leaver et al., 2019b; Gumede et al., 2022). Specialists have a short distribution range and are patch-specific, which makes them more susceptible to disturbances and local extinction (Leaver et al., 2019a, b; Zakaria et al., 2005; Canterbury et al., 2000; Ngcobo et al., 2022).

1.3 Vegetation as an indicator of forest status

The arrangement and the makeup of the forests determine the integrity and the physiognomy of the forest (Babaasa et al., 2004; Lawes et al., 2007). Forests that have been heavily disturbed tend to differ from those that are relatively intact in terms of structural makeup, species diversity, and size (Denslow and Hartshorn, 1994; Babaasa et al., 2004; Leaver et al., 2019b; Bitani et al., 2023a). Canopy opening as a result of disturbances alters the growth and succession of secondary forest species because of lianas and pioneer species growth (Denslow and Hartshorn, 1994; Hall et al., 2003; Kleinschroth et al., 2013). This influences the microclimate attributes in the forest (Okuda et al., 2019; Kreutzweiser et al., 2020). Species such as *Zanthoxylum gillettii* are likely to have a good number of seedlings in the presence of light (Makana and Thomas, 2006), indicating the opening of gaps in the forest because of disturbances and the growth of light-dependent species (*Mimulopsis solmsii, Pteriduum aquailium, and Robus steudneri*) (Babaasa et al., 2004). In the Gxalingenwa forest (a forest that was heavily logged a long time ago) in KwaZulu-Natal, the gaps in the canopy and the dominant thicket understory in the present time are an indication of disturbances that took place years ago (Nomtshongwana, 1999; Lawes et al., 2007).

The forest vegetation makeup is, therefore, crucial to consider as it provides meaningful insights into the forest functioning and disturbance intensity (Leaver et al., 2019b; Bitani et al., 2023a). The use of disturbance-sensitive species may assist in determining the effect of the disturbance; for example, the presence of *Ocotea* spp. informs on patch quality, as they are sensitive to disturbances (Nomtshongwana, 1999; Kleinschroth et al., 2013). Depending on the type and intensity of disturbance, tree diversity varies, as some disturbances target large mature trees, resulting in the open canopy and growth of pioneers and invasives (Laurance, 1991; Lawes et al., 2007; Kreutzweiser et al., 2020; Bitani et al., 2024). Apart from diversity, species density is also an important measure, with more density occurring in relatively intact forests (Besi et al., 2023; Hall et al., 2003). However, higher stem densities are common in logged forests along small-sized trees (Rutten et al., 2015; Hall et al., 2003; Makana and Thomas, 2006; Senior et al., 2018; Okuda et al., 2019), indicating the regeneration of secondary vegetation from heavy disturbances (Denslow and Hartshorn, 1994; Makana and Thomas, 2006). Furthermore, the higher stem density may be attributed to the introduction of pioneers and invasive species (Lewis et al., 2015). Consequently, the recovery process of native species after disturbance is affected (Kleinschroth et al., 2013). This was evident when the saplings and tree densities did not recover even after 18 years of post-logging activities in the southern Central African Republic (Hall et al., 2003). Thus, it is important to assess the disturbances and their extent for conservation and management (Hall et al., 2003; Makana and Thomas, 2006; Besi et al., 2023).

1.4 Birds as indicators of forest status

Anthropogenic activities in the forest filter the ecological traits of bird species (Canterbury et al., 2000; Zakaria et al., 2005; Weeks et al., 2023). Species with certain ecological traits survive severe disturbances and have less preference in terms of habitat selection, and they are known to have a wider ecological niche (Kassen, 2002; Arcilla et al., 2015; Weeks et al., 2023). Functional diversity and species composition in the disturbed and relatively undisturbed forests are different, and therefore, appropriate to inform on the forest integrity (Zakaria et al., 2005; Nguyen, 2007; Piratelli et al., 2008; Leaver et al., 2019a, b; Gumede et al., 2020). In Malaysia, the composition of species and species diversity is high in the relatively intact forests when compared with the disturbed forests (Zakaria et al., 2005). Meanwhile, the species richness abundance of the avifaunal community may be a bit misleading because of the generalists replacing specialist species in disturbed forests (Canterbury et al., 2000; Zakaria et al., 2005; Leaver et al., 2019a).

There will likely be a species turnover in specialist species, while generalists will increase in abundance or remain unaffected (Zakaria et al., 2005; Leaver et al., 2019b). For example, ground-nesting birds such as orange ground-thrush (*Geokichla gurneyi*) and lemon dove (*Columba larvata*) are some of the forest specialists that are highly susceptible to disturbances (Nguyen, 2007; Piratelli et al., 2008; Gumede et al., 2020). The presence of these species in the forest informs the relative intactness of the forest and, therefore, provides a better perspective for conservation majors (Gumede et al., 2020). In southeast Malaysia, Zakaria et al. (2005) reported a decrease in the abundance of specialist moustached babbler (*Malacopteron magnirostre*) species in the logged forest, while the generalist red-eyed bulbuls (*Pycnonotus brunneus*) and grey-bellied bulbul (*Pycnonotus cyaniventris*) increased. The overall avifaunal community is the effective predictor of forest quality (Canterbury et al., 2000; Leaver et al., 2019a, b; Gumede et al., 2022). In a recent study, the avifaunal community was directly linked to increased patch size (Gumede et al., 2022), which is an indication of forest status (Leaver et al., 2019a, b) as small-sized habitats indicate habitat fragmentation (Zungu et al., 2020a, b). Therefore, it is recommended to consider the avifaunal community as a predictor of forest status to avoid gaps and misleading results (Zakaria et al., 2005; Leaver et al., 2019a, b).

1.5 Problem statement

Forest habitats have considerably decreased since decades ago (King, 1941; Kairu et al., 2013; Armenteras et al., 2023). Their susceptibility to anthropogenic activities persists because of insufficient management (Obiri et al., 2002; Muhanguzi et al., 2007; Kung'u et al., 2023). However, the forest-human interactions are highlighting the need for the stoppage of forest declines as a result of an imbalance in ecosystem services and conservation implications (Dagba et al., 2017; Constant and Taylor, 2020; Bentsi-Enchill et al., 2022). Balancing these is important for forest health maintenance while providing ecosystem services to biodiversity and communities (Constant and Taylor, 2020). Excessive use of these forests results in overexploitation of their resources, which negatively impacts their integrity and biodiversity (Kairu et al., 2013; Lewis et al., 2015; Sosibo et al., 2022b; Kung'u et al., 2023).

Severe disturbances result in the local extinction of species that play a crucial role in ecosystem functions (Zakaria et al., 2005). Understanding these disturbances' impact on species will allow for the implementation of proper conservation measures (Leaver et al., 2019a, b; Sullivan et al., 2022; Esaete et al., 2023). Therefore, the use of forest fauna is crucial to assess these disturbances as they tell us more about the condition of the forest (Ross et al., 2018; Steffens and Lehman, 2019; Leaver et al., 2019a, b; Kpan et al., 2021; Sosibo et al., 2022a; Kung'u et al., 2023). This concept is based on their ecological behaviour, which is very sensitive to the changing environment and disturbances (Gumede et al., 2022; Sosibo et al., 2022a). One of the most widely used is the avifauna, which are highly mobile, and explore a variety of ecological niches (see Leaver et al., 2019a, b; Maseko et al., 2019; 2020; Gumede et al., 2022; Weeks et al., 2023; Bitani et al., 2023a, b).

Moreover, the vegetation makeup of the forest can dictate the magnitude of disturbances in the forest (Hall et al., 2003; Adie et al., 2013; Rutten et al., 2015; Bitani et al., 2023a). The forest vegetation is also compromised by the anthropogenic activities the forest experiences (Lewis et al., 2015; Leaver and Cherry, 2020). Therefore, it is crucial to consider vegetation when assessing forest disturbances. In addition, the perceptions of the communities that reside near the forests are also essential to consider (Robertson and Lawes, 2005; Armenteras et al., 2023). How the forests benefit them may be important to balance the ecosystem services and conservation implications (Constant and Taylor, 2020). Therefore, we assessed forest disturbances to satisfy the aims and objectives of this study.

1.6 Aims and objectives

This study aimed to determine bird species diversity at the local landscape scale between the mistbelt forest patches that have been heavily disturbed, medium disturbed, and relatively undisturbed Indigenous forests in southern KwaZulu-Natal, South Africa. Therefore, the study compared the effect of disturbance on bird species and vegetation and included the perspectives of the nearby community on forests. The following objectives were used to satisfy our aim:

- To determine the structural complexity and heterogeneity between the heavily disturbed, medium disturbed, and relatively undisturbed mistbelt indigenous forests that occur at a similar landscape in KwaZulu-Natal;
- To determine the functional and taxonomic diversity of bird species between the heavily disturbed, medium disturbed, and relatively undisturbed mistbelt indigenous forests that occur in a similar landscape in KwaZulu-Natal;
- To determine the impact of heavily logged mistbelt indigenous forest on the nearby communities in KwaZulu-Natal and
- To assess the perceptions of human communities on the impacts of heavy logging on their nearby forests in KwaZulu-Natal.

1.7 Structure of the thesis

This thesis contains five chapters. The first chapter (Chapter 1) is a brief introduction that includes the aims and objectives of the study. It contains a problem statement section that is being addressed. The second chapter (Chapter 2) is a systematic review whereby the relevant literature on forest-anthropogenic activities was synthesised for forests in Africa to highlight trends. The third chapter (Chapter 3) is a data chapter based on how birds' functional and taxonomic diversity respond to structural complexity and heterogeneity differences as a result of forest disturbances. The fourth chapter (Chapter 4) examines communities' perspectives on the impact of disturbance and the importance and values of the forests. Lastly, the fifth chapter (Chapter 5) is the general discussion, conclusions and recommendations. The data chapters in this thesis are formatted for submission to peer-reviewed journals; therefore, some repetition was impossible to avoid. Finally, all the predictions and research questions are presented in each respective data chapter.

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CHAPTER 2

Effects of anthropogenic activities on indigenous forests in Africa: A systematic review

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Running header: Anthropogenic forest disturbances in Africa.

2.1 Abstract

Forests play a major role in the provision of ecosystem services and atmospheric regulation. However, in Africa, indigenous forests have been subjected to different disturbances that vary in magnitude. The severity of these disturbances negatively impacts forest structure and composition. We conducted a systematic review to assess the anthropogenic effect on African forests. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, we systematically searched for relevant articles using different search engines. We found 60 articles which met our selection criteria from January 2000 to June 2023. There was a bias in years of publications, with most articles (10%) published in 2013. There was also an unequal geographical distribution of these articles, with the highest (20%) published in South Africa. With regards to disturbances, logging was the most common disturbance across Africa, with over 40% of research efforts examining it. Other disturbances in forests were examined to a lesser extent. These disturbances were found to negatively impact the structure and composition of forests. The decreased richness of mature trees, saplings, and seedlings altered the forest canopy, and regeneration of secondary forests. Other studies assessed the disturbances in the forest using the forest fauna as bioindicators. Therefore, for the management and conservation of these forests, agroforestry, selective logging, and cooperation with local people may be the avenues for success.

***Keywords*:** Forest ecosystems; Anthropogenic activities; Biodiversity; Forest structure; Forest composition

2.2 Introduction

The terrestrial ecosystem depends on forests as their principal habitat and ecological functioning globally (Lawes et al., 2004; Djagoun et al., 2022; Dar et al., 2022). Forests provide a variety of ecosystem services, ranging from biodiversity support to human-subsistence requirements, especially in developing countries of Africa (Fisher, 2004; Burgess et al., 2007; Paumgarten and Shackleton, 2011; Sullivan et al., 2022). Namely, forests are home to endangered species such as the Cape parrot (*Poicephalus robustus*) in South Africa (Downs et al., 2014; Rea et al., 2023) and provide habitat and feeding requirements to the avian and mammalian communities (Laurance et al., 2007; Caves et al., 2013; Cordeiro et al., 2015; Asefa et al., 2017; Gumede et al., 2022; Sosibo et al., 2022a, b; Zungu et al., 2022b). In addition, forests play a crucial role in atmospheric regulation through carbon stock and sequestration, which plays a role in local climate regulation and the accumulation of vegetation that is exclusive to forest characteristics (Jenkins and Schaap, 2018; Bentsi-Enchill et al., 2022). In rural communities, there is a considerable and growing reliance on forests for the supply of services, including building facilities, fuel energy, medicine, and cultural as well as spiritual beliefs (Shackleton and Shackleton, 2004; Shackleton et al., 2007; Ofoegbu et al., 2017; Dar et al., 2022; Bentsi-Enchill et al., 2022).

Nevertheless, the role of African forests is increasingly at risk because of anthropogenic activities (Barlow et al., 2016; Tegegne et al., 2016; Dagba et al., 2017; Sullivan et al., 2022). Human-mediated activities, including the exploitation of forest resources, mining, commercial logging, and agriculture, echo the rate at which the forests are threatened (King, 1940; Rycroft, 1944; Hall et al., 2003; Ofoegbu et al., 2017; Sullivan et al., 2022). The growing human population has drastically increased the rate at which these forests are anthropogenically disturbed (Dar et al., 2023). As a result, the forests have been fragmented and disconnected into smaller patches (see Rycroft, 1944; Mbakwe, 1986; Fahrig, 1997; 2003; Hall et al., 2003;

Babaasa et al., 2004; Rutten et al., 2015; Ehlers Smith et al., 2021; Sullivan et al., 2022; Ngcobo et al., 2022). The increased rate of forest loss is also exacerbated by the proximity between human communities and forests (Bentsi-Enchill et al., 2022). Land conversion for agriculture and mining has increased deforestation, logging, fragmentation, and degradation, influencing the forest's structural complexity and heterogeneity (Rycroft, 1944; Rutten et al., 2015; Dagba et al., 2017; Dar et al., 2022; Weeks et al., 2023).

Forest complexity accounts for the greater diversity of functional communities found in the forest (White, 1981; Rutten et al., 2015). Structure and composition are the two most crucial covariates of the forest habitat make-up (Lawes et al., 2004; 2007; Bitani et al., 2023a). Hence, the impact of anthropogenic activities on the forests' structure and composition requires more attention (Hall et al., 2003; Down and Symes, 2004; Makana and Thomas, 2006; Ehlers Smith et al., 2019, 2021; Bitani et al., 2023a, b). In Ghana, the decreased species heterogeneity is exacerbated by high disturbance pressures (Bentsi-Enchill et al., 2022), which causes a turnout in the soil quality and nutrient composition primarily required by the accumulation of forest vegetation. The vegetation turnout challenges the composition and causes the invasion of pioneers and exotic species, prohibiting the recruitment of secondary succession (Hall et al., 2003; Babaasa et al., 2004; Makana and Thomas, 2006; Kleinschroth et al., 2013).

Secondary succession is important for the re-establishment of disturbed forests. Although the process is slow, pioneers and exotic species make the process impossible, resulting in the loss of forest habitat patches and challenges the provision of ecosystem services and their biosphere (Shackleton et al., 2019; Dar et al., 2022; DeArmond et al., 2023). Therefore, using existing knowledge to close gaps is essential to provide management improvements. In the present study, we (1) provided a conceptualised synthesis of existing knowledge on African forest-anthropogenic activities, (2) assessed their impact on forest structure and composition, and (3) provided the management implications for the disturbances in indigenous forests.

2.3 Methods

2.3.1 Data collection

We conducted a systematic review of forest-anthropogenic activities in Africa following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). Generally, the systematic review is a useful approach to synthesise the literature while focusing on a specific over-arching topic. Following the PRISMA protocols, the progress is easily monitored, improving the reliability and transparency between the readers and the reviews (Haddaway et al., 2015). This provides more clarity and responsibility in decision-making throughout the review process. In addition, a systematic review increases the possibility of replicating the study, lowering the chances of biases (Haddaway et al., 2020).

We obtained the published literature on African forest-anthropogenic activities from Google Scholar® (https://scholar.google.com/), Scopus® (https://www.scopus.com/), Science Direct® (https://www.sciencedirect.com/), Web of Science® (https://www.webofscience.com/), and PubMed® (https://pubmed.ncbi.nlm.nih.gov/). We specifically searched for literature on the impact of anthropogenic activities on forests using different search techniques. Our key searches included forest AND destruction OR forest AND disturbance OR forest AND logging OR forest AND degradation OR forest AND conversion, AND forests AND Africa. These searches were all conducted without a year's restriction.

2.3.2 Inclusion and exclusion criteria

Publications on African forest-anthropogenic activities were considered provided they meet our minimum requirements (Figure 2.1). In this review, we only considered publications that assessed the impact of anthropogenic activities on indigenous forests in Africa. Therefore, we excluded papers based on their topic, abstract, and full-text review. Considering that we used different search engines with similar keywords, some of the papers were duplicated and excluded. We excluded most of the studies that were outside Africa at the topic level. No study done outside of the forest biome was considered in this study. Furthermore, we excluded studies on natural disturbances such as environmental impacts, including wildfires, climate change, and natural hazards. Studies that were conducted on exotic plantations rather than indigenous forests were also excluded. Studies that were literature reviews and case studies were also not considered in this study. For studies that assessed the forest fauna, they were included only when they also assessed the forests' structure or composition or both. Specifically, they had to show the trends of changing forest fauna along with vegetation as a result of anthropogenic disturbance.

Finally, we analysed the data using Microsoft Excel®. Our analyses included only descriptive statistics, including frequencies.

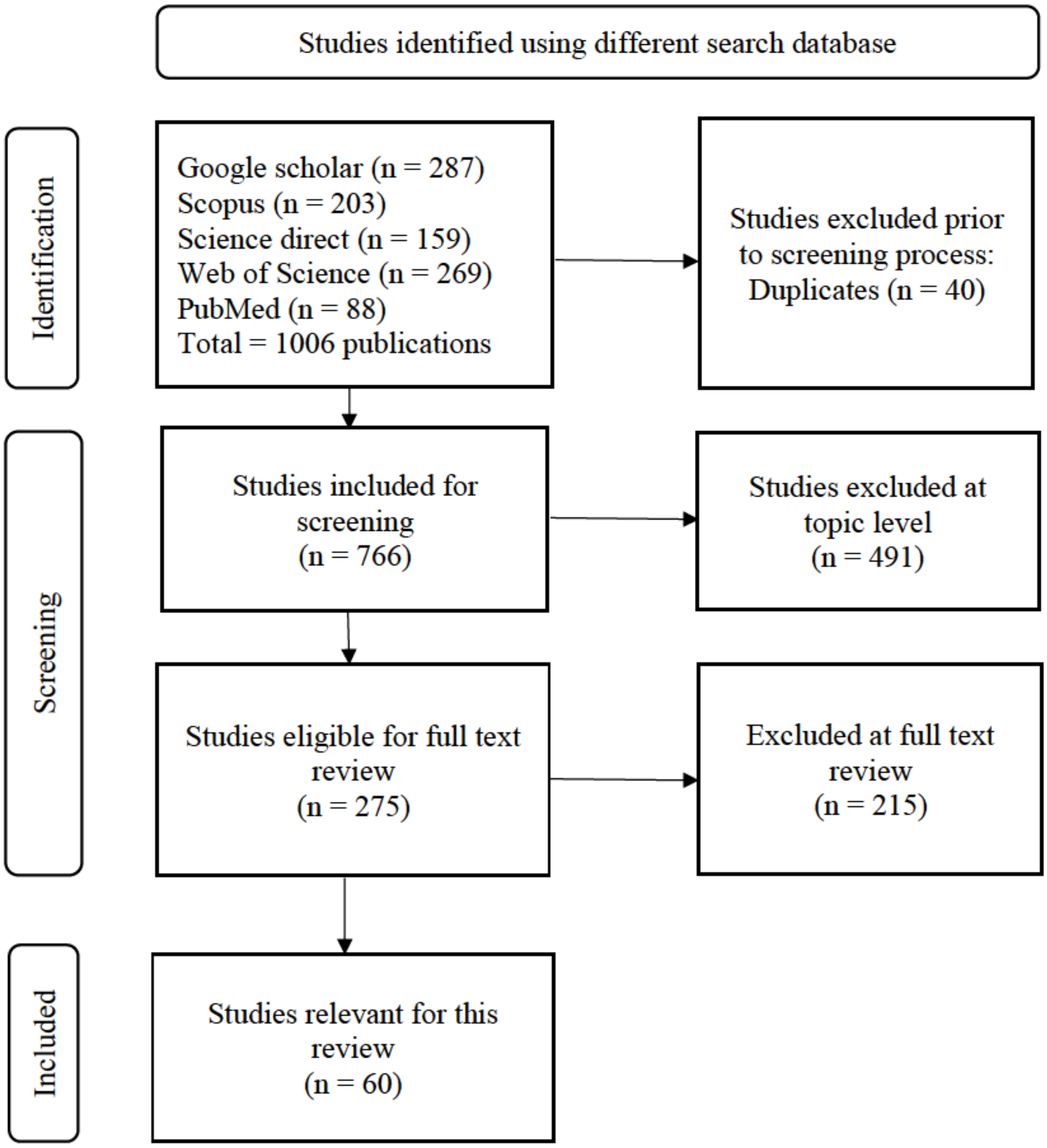

Figure 2.1: The flow chart for the inclusion and exclusion of studies as per PRISMA guidelines (Page et al., 2021), and summary of papers found and reviewed.

2.4 Results

We identified a total of 60 publications relating to African forest-anthropogenic activities from 2000 to July 2023. The forest research effort in Africa has been inconsistent over the years (Figure 2.2). Most studies were published in 2007, 2013, and 2020 with a proportion of 8%, 10%, and 8%, respectively. These studies were published across 14 African countries (Figure 2.3). The distribution of publications showed a bias with about 60% of the studies conducted in only five African countries, namely South Africa (20%), Kenya (13%), Uganda (12%), Central African Republic (10%), Ghana and Tanzania (8%).

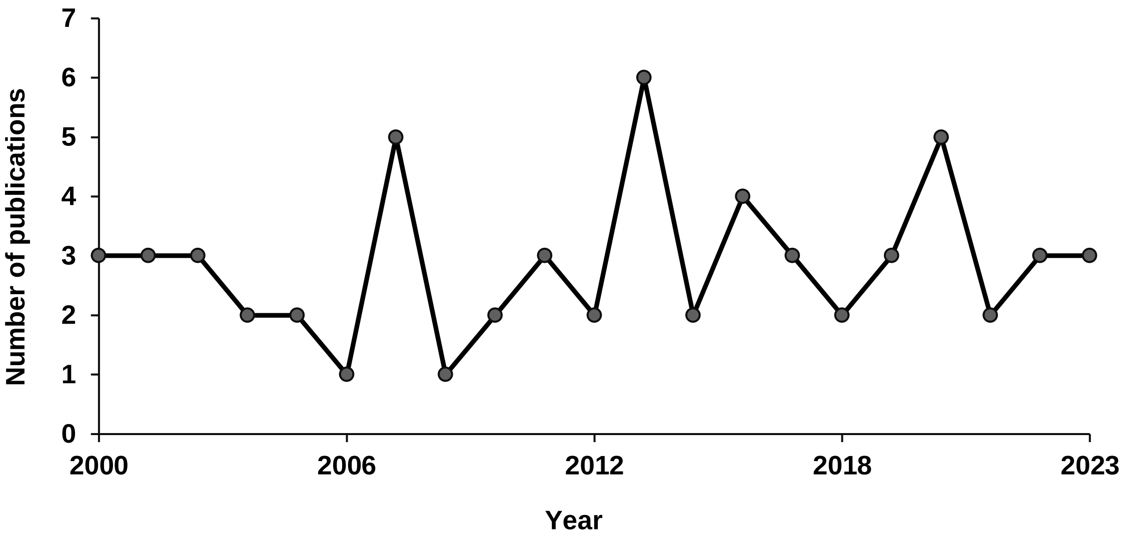

Figure 2.2: The number of research publications on African forests and the impact of anthropogenic disturbances from 2002 to July 2023.

From the publications, we found a variation in the anthropogenic disturbance type affecting African forests (Supplementary Information Table S2.1). However, the research effort was biased in terms of the assessment of these disturbance types. Most studies (45%) assessed the impact of logging on the forests (Figure 2.4). Other notable efforts in these studies were on harvesting (22%), fragmentation (7%), degradation (5%), and other (22%). Some publications assessed different disturbance types simultaneously, and we referred to them as “Other” (Figure 2.4). Some of these disturbance types included overexploitation, land use, overexploitation, etc. (see Supplementary Information Table S2.1).

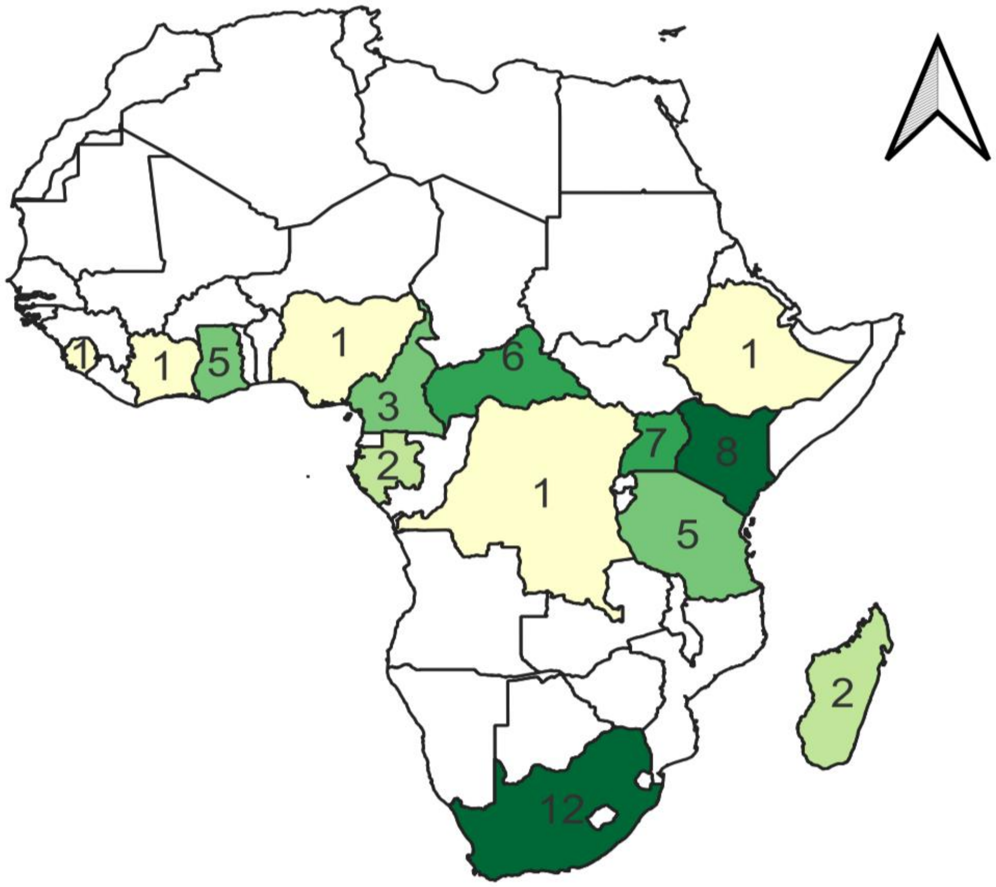

Figure 2.3: The number of publications on forest-anthropogenic disturbances in Africa (n = 60) from 2002 to July 2023. The rest of the studies (n = 5) were conducted in multiple countries such as Ghana, Cameroon, Gabon, Sierra Leone, Uganda, Kenya, and Tanzania.

Furthermore, these African forest anthropogenic disturbances were assessed at both patch and landscape scales, with the landscape scale being the most explored (52%) (Supplementary Information Table S2.1). As the interest of this review was on forest structure and composition, most studies assessed the forest structure more than the composition, with relatively few studies assessing both at once (Supplementary Information Table S2.1). To a lesser extent (23%), some studies have used forest fauna as indicators of the forest structure and composition. However, there was still a gap and bias in using indicator species to assess the forest functioning, as 13% of these were done solely on avian indicators (Supplementary Information Table S1). Only 10% of studies used mammals, amphibians, insects, and primates as forest habitat indicators (Supplementary Instruction Table S2.1).

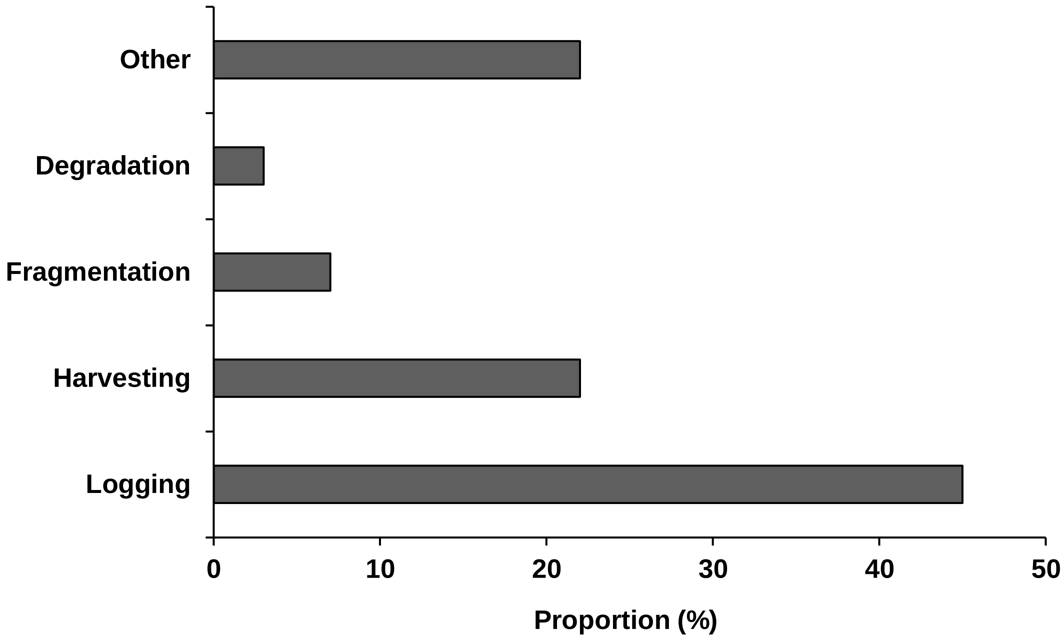

Figure 2.4: The proportion of research focus on anthropogenic disturbances in African forests in reviewed publications from 2000 to July 2023.

2.5 Discussion

African forests continue to be threatened as anthropogenic disturbances become severe with the exponential growth of the human population (Adie et al., 2013; Kidane et al., 2016; Attua et al., 2018). The means of understanding the dynamics of these disturbances have been adopted for the last decades (Eely et al., 1999; Lawes et al., 2004; Van Gemerden et al., 2003a; Babaasa et al., 2004; Shackleton et al., 2019). To date, the patterns of disturbances have been assessed, but there are no initiatives for effective management (Adie et al., 2013; Shackleton et al., 2019).

2.5.1 Impact of anthropogenic disturbances on forest structure and composition

Over 40% of research efforts conducted on logging and its impact on forest structure and composition have been well-studied across Africa (Hall et al., 2003; Van Gemerden et al., 2003b; Makana and Thomas, 2006; Asase et al., 2012; Cazzolla Gatti et al., 2015; Ross et al., 2018; Kpan et al., 2021; Sullivan et al., 2022). Logging has also been a threat to forest structure and composition for decades outside Africa, as reported in Asia and South America (e.g., Zimmerman and Kormos, 2012; Mestre et al., 2020; DeArmond et al., 2023). Apart from logging, other common anthropogenic disturbances (e.g. fragmentation, harvesting, degradation) in African forests have been documented (Leaver et al., 2019a, b; Araia et al., 2020; Zambrano et al., 2020). Disturbances have been responsible for the opening of routes by large skidders and tractors inside forests to extract trees for timber, as reported in Central Africa (Malcolm and Ray, 2000; Hall et al., 2003). During timber extraction, medium and larger trees are targeted because they are preferred over small-sized trees (Malcolm and Ray, 2000; Hall et al., 2003; Addo-Fordjour et al., 2013; Jucker et al., 2016). The structural complexity and heterogeneity are compromised as a result (Jucker et al., 2016; Attua et al., 2018). Similar findings have been reported in Brazil (DeArmond et al., 2023).

However, the density of saplings was not significantly different between the logged and unlogged forests (Malcom and Ray, 2000). On the contrary, Hall et al. (2003) found a relatively lower density of saplings in logged forests. This contrast is explained by seedling abundance, which determines the success rate of sapling regeneration (Kidane et al., 2016). In Tanzania and Uganda, the density of trees in unharvested forests was double that of harvested forests, which were mostly used for building poles (Ndangalasi et al., 2007).

Species that are prone to disturbances are most likely to decrease in abundance, diversity, and composition, favouring the accumulation of pioneer and exotic species

(Kleinschroth et al., 2013; Rutten et al., 2015; DeArmond et al., 2023). In Congo, *Zynthoxylum gilletii* was found to be dominant in disturbed forests because of its resistance to disturbance as they favoured open canopy (Makana and Thomas, 2006). The pioneer and exotic species prohibit the regeneration of late-succession species, such as *Ocotea usambarensis*, as reported in Kenya and Tanzania (Kleinschroth et al., 2013; Zambrano et al., 2020). This was also the case in Uganda, where severe disturbances resulted in lower distribution, reducing tree species' stem density and diversity (Kasenene, 2007; Muhanguzi et al., 2007). Similar to Uganda, the richness and composition of tree species was found to be lower in disturbed forests compared with the relatively intact forest in Cameroon, Kenya, and Central Africa (Van Gemerden et al., 2003b; Hall et al., 2003; Oyugi et al., 2008).

The overall floristic composition in disturbed forests is relatively lower than in relatively intact forests (Bitariho et al., 2023). The latter is driven by the decreased species richness, diversity and composition of seedling banks (Esaete et al., 2023; Bitariho et al., 2023). In Tanzania, the functional richness was found to be lower in disturbed forests as a result of low wood density (Zambrano et al., 2020). The low seedling banks are a result of the lower density and the absence of mature trees as a result of species-specific harvesting (Esaete et al., 2023). Therefore, the forest community and the forest fauna are severely affected and face the risk of depletion and local extinction (Fahrig et al., 1997; Sekerciouglu, 2012; Bełcik et al., 2020; Sosibo et al. 2022a, b).

2.5.2 Forest fauna as indicators of forest-anthropogenic effects

The forest fauna can be used as an indication of forest functioning and health. This is because the specialist species in the forest are highly dependent on the specific vegetation type for their ecological niche (Maseko et al., 2019; 2020; Gumede et al., 2020; Ehlers Smith et al., 2021; Ngcobo et al., 2022; Bitani et al., 2023a, b). Therefore, assessing these species with specific ecological niches can provide robust evidence of forest functioning and health. However, we noted that the latter has a relatively poor research effort in Africa (Supplementary Instruction Table S2.1). Nonetheless, the forest fauna is also severely affected by the disturbed structure and composition (Kpan et al., 2021; Kung'u et al., 2023). In Kenya, forest understory was crucial for arthropod abundance as influenced by leaf litter (Ross et al., 2015; Kung'u et al., 2023). This was also the case in the Ivory Coast, where altered structures negatively affected the abundance of amphibians (Kpan et al., 2021). In Central Africa, there is evidence of decreased mammal richness as a result of the altered forest canopy (Malcom and Ray, 2000).

The disturbances that result in an altered forest canopy are the main driver of decreasing tree diversity, vegetation structure, and mammal abundance (Malcom and Ray, 2000; Deere et al., 2020). Some tree species are target species from both wild animals and humans which increases pressure on these species (Steffens and Lehman, 2019; DeArmond et al., 2023). In Tanzania, relatively intact forests were found to be crucial for the diet of primate species, and disturbance affected the diet of these primates, resulting in local extinction (Bracebridge et al., 2012; Steffens and Lehman, 2019).

Several forest disturbances may result in reduced forest size and patch isolation, posing a threat of edge effects to forest avifaunal (Manu et al., 2007; Mammides et al., 2015). In some countries like Ghana, Kenya, Uganda, and Nigeria, the edge effect decreased avian richness and abundance (Beier et al., 2002; Manu et al., 2007; Mammides et al., 2015). This decrease in richness is driven by altered forest structure and composition because of severe disturbances (Mammides et al., 2015; DeArmond et al., 2023). In South Africa, there was a correlation between the response of plant and avian diversity to forest disturbance (Grass et al., 2015). The reduced tree abundance in forests as a result of uncontrolled harvesting has a negative impact on the diversity of avian communities (Leaver et al., 2019a, b), which advocates the need for the management and conservation of forest communities. In South America, the avian community, especially terrestrial, understorey, and canopy species, were more affected by the severe disturbance (Weeks et al., 2023). Additionally, Mestre et al. (2020) found a lower functional diversity in logged forests as a result of specialist species loss.

2.5.3 Conservation implications and management of African forests

Conservation that is based on proactive conservation measures and practices is required in African forests as a result of anthropogenic pressures on forest ecosystems (Lyaruu et al., 2000; Makana and Thomas, 2006; Oyugi et al., 2008; Mwakosya and Mligo, 2014; Grass et al., 2015; Jucker et al., 2016; Maseko et al., 2020; Bitani et al., 2023b). In addition, the regenerating old-growth forests are also of major concern for protection and conservation (Sullivan et al., 2022; Esaete et al., 2023). As these forests are believed to have the potential to have similar attributes to primary forests, they are the future of the forest ecosystem (Makana and Thomas, 2006; Rutten et al., 2015; Maseko et al., 2019).

Landscape degradation resulting in forest fragmentation should be minimised (Zambrano et al., 2020; Araia et al., 2020). This is a major cause of the forest-edge effects resulting in disconnected forest patches and isolation (Fahrig, 2003; Manu et al., 2007; Steffens and Lehman, 2019; Zebaze et al., 2022). Therefore, the impacts of forest disturbances should be studied in detail, giving priority to species regeneration, functional diversity, and monitoring for the response and resilience of these forests overtime (Babaasa et al., 2004; Ndangalasi et al., 2007; Kairu et al., 2013; Sullivan et al., 2022).

The majority of the forest patches in Africa are located nearby communities (Shackleton and Shackleto, 2006; Shackleton et al., 2007). The strong communication and cooperation of local communities and various stakeholders can improve the management of these forests (Adie et al., 2013; Kidane et al., 2016). The recommended management exercise may include the three most important. The first one is agroforestry, which will assist in the plantation of forests and, crucially, the rare species on the verge of being wiped out (Kleinschroth, 2013; Bentsi-Enchill et al., 2022; Kung'u et al., 2023). The second is selective logging, which may be used to avoid illegal logging of rare species, especially larger timber (Sullivan et al., 2022). Thirdly, collaboration with community members for sustainable harvesting and effective management (Kidane et al., 2016).

2.6 Conclusions

The impacts of anthropogenic disturbances on African forests vary depending on the severity, scale and type of disturbance. They negatively influence the distribution of species and density. The make-up of the forest ecosystem and regeneration processes are also affected in the long run. Anthropogenic activities, particularly logging, are the major causes of structural differences with relatively low density, richness, and diversity. In the disturbed forests, there is a high abundance of early succession species that are disturbance-tolerant, which interfere with the secondary regeneration of late succession species that are susceptible to disturbances. Moreover, decreased seedling and saplings richness and diversity lowers the recovery rate of secondary forests. These disturbances may negatively affect functional diversity when extreme, resulting in recovery failure. Although the process may be slow, the secondary forest can accumulate similar attributes as the primary forest in the future. It is, therefore, important to measure these disturbances. Specifically, their severity and scale advocate the functioning of the forest ecosystem in the future.

Bioindicators of forest health and ecosystems are important to consider when assessing forest disturbances. Forest fauna, especially specialist species, are sensitive to changing forest structure and composition and can be useful in informing the forest health status (Cazzolla Gatti et al., 2015; Sullivan et al., 2022). Disturbances that result in canopy removal, habitat fragmentation, as well as edge effects decrease the functional diversity and richness of the specialist species (Beier et al., 2002; Manu et al., 2007; Steffens and Lehman, 2019). As a result, raising precautions and interventions for protecting the forest is of the utmost importance and should be implemented with immediate effect. Afforestation may be necessary for forest cover, supplementing the endangered and rare species. This may also be useful for commercial purposes, and most timber harvesting occurs for commercial purposes. Cooperation between conservation organisations and local people is necessary to successfully manage and conserve African forests. Furthermore, more research output is needed to understand the regeneration, functional diversity and resilience of these forests in the long run. Although the focus was on Africa, the trends are similar to those of other tropical and temperate forests in developing countries, especially in the southern hemisphere.

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2.8 References

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2.9 Supplementary Information

Supplementary information Table S2.1 Summary of studies on anthropogenic activities in African forests

Authors	Year	Country	Disturbance type	Scale	Forest type	Forest matrix	Indicator	Implications
Malcom & Ray, 2000	2000	Central African Republic	Logging	Patch	Rainforest	Structure and composition	Mammals	Further research
Reed & Clokie, 2000	2000	Uganda	Grazing and Cultivation	Patch	Montane	Composition	na	Maintenance
Lyaruu et al., 200	2000	Tanzania	Degeneration	Patch	Afromontane	Composition	na	Conservation
Sekercioglu, 2002	2002	Uganda	Forestry	Patch	Tropical	Structure	Avian	Further research
Beier et al., 2002	2002	Ghana	Fragmentation	Patch	Tropical	Structure	Avian	Further research
Obiri et al., 2002	2002	South Africa	Exploitation	Patch	na	Structure	na	Management practise
Hall et al., 2003	2003	Central African Republic	Logging	Patch	Evergreen	Structure and composition	na	Management
Van Gemerden et al., 2003	2003	Cameroon	Logging	Landscape	Rainforest	Structure	na	Further research
Van Gemerden et al., 2003	2003	Cameroon	Land use	Patch	Rainforest	Composition	na	Further research
Babaasa et al., 2004	2004	Uganda	Logging	Both	Afromontane	Composition	na	Monitoring
Brown & Gurevitch, 2004	2004	Madagascar	Logging	Patch	Tropical	Structure	na	none
Boudreau & Lawes, 2005	2005	South Africa	Harvesting	Patch	Scarp	Composition	na	Further research
Boudreau et al., 2005	2005	South Africa	Harvesting	Patch	Scarp	Structure	na	Further research
Makana & Thomas, 2006	2006	Congo	Logging	Landscape	Tropical	Structure	na	Protect/conserve
Ndangalasi et al., 2007	2007	Tanzania, Uganda	Harvesting	Landscape	Montane	Structure	na	Monitoring
Manu et al., 2007	2007	Nigeria	Fragmentation	Patch	na	Structure	Avian	Minimize fragmantation
Kasenene, 2007	2007	Uganda	Logging	Both	Afromontane	Composition	na	Management
Lawes et al., 2007	2007	South Africa	Logging	Landscape	Mistbelt	Structure	na	Limit harvesting
Muhanguzi et al., 2007	2007	Uganda	Harvesting	Landscape	Afromontane	Structure	na	Management
Oyugi et al., 2008	2008	Kenya	Logging	Landscape	Coastal	Composition	na	Protect/conserve
Ahrends et al., 2010	2010	Tanzania	Degradation	Landscape	na	Structure	na	na
Kirika et al., 2010	2010	Uganda and Kenya	Logging	Landscape	Tropical	Structure	na	Further research

Furukawa et al., 2011	2011	Kenya	Extraction	Patch	Semi-deciduous	Structure	na	Further research
Ouedraogo et al., 2011	2011	Central African Republic	Logging	Landscape	Moist forest	Composition	na	none
Gliniars, 2011	2011	Uganda and Kenya	Harvesting	Landscape	Rainforest	structure	na	none
Asase et al., 2012	2012	Ghana	Logging	Landscape	Tropical	Structure	na	Comparative data
Bracebridge et al., 2012	2012	Tanzania	Logging	Landscape	Montane	Structure	Primates	Conservation
Gourlet-Fleury et al., 2013	2013	Central African Republic	Logging	Landscape	Tropical	Composition	na	Management
Adie et al., 2013	2013	South Africa	Logging	Landscape	Afrotemperate	Structure and composition	na	Partnership
Kleinschroth, 2013	2013	Kenya	Logging	Landscape	Montane	Structure	na	Enrichment planting
Gourlet-Fleury et al., 2013	2013	Central African Republic	Logging	Landscape	Tropical	Structure	na	Limit logging
Kairu et al., 2013	2013	Kenya	Overexploitation	Patch	Montane	Structure	na	Further studies
Addo-Fordjour et al., 2013	2013	Ghana	Degradation	Patch	Rainforest	Structure	na	Further studies
Decocq et al., 2014	2014	Central African Republic	Logging	Patch	Tropical	Structure	na	Forest community
Mwakosya & Mligo, 2014	2014	Tanzania	Harvesting	Patch	Montane	Structure	na	Conservation
Cazzolla Gatti et al., 2015	2015	Sierra Leone Ghana, Cameroon, Gabon	Logging	Landscape	Tropical	Structure and composition	na	Further research
Grass et al., 2015	2015	South Africa	Modification	Patch	Scarp	Composition	Avian	Preserve natural forests
Mammides et al., 2015	2015	Kenya	Logging	Patch	Tropical	Composition	Avian	Forest managemebt
Rutten et al., 2015	2015	Kenya	Logging	Landscape	Montane	Structure and composition	na	Management
Chiti et al., 2016	2016	Ghana, Cameroon, Gabon	Logging	Landscape	Tropical	Composition	na	Further research
Jucker et al., 2016	2016	Sierra Leone	Logging	Landscape	Rainforest	Structure	na	Safeguard
Kidane et al., 2016	2016	Ethiopia	Harvesting	Patch	Afromontane	Structure	na	Management
Attua et al., 2018	2018	Ghana	Anthropogenic	Landscape	Rainforest	Structure	na	Management
Ross et al., 2018	2018	Kenya	Logging	Landscape	Rainforest	Structure	Insects	Further research
Leaver et al., 2019	2019	South Africa	Harvesting	Patch	Afromontane	Structure	Avian	Further research
Leaver et al., 2019	2019	South Africa	Harvesting	Landscape	na	Structure	Avian	Further research
Steffens & Lehman, 2019	2019	Madagascar	Fragmentation	Patch	Dry forest	Structure	Primates	Management

Leaver & Cherry, 2020	2020	South Africa	Harvesting	Landscape	na	Structure	na	Licencing
Araia et al., 2020	2020	South Africa	Anthropogenic	Landscape	na	Composition	na	Management
Leaver & Cherry, 2020	2020	South Africa	Harvesting	Landscape	na	Structure	na	Further research
Zambrano et al., 2020	2020	Tanzania	Fragmentation	Landscape	na	Composition	na	Management
Iponga et al., 2020	2020	Gabon	Anthropogenic	Patch	Rainforest	Composition	na	none
Kpan et al., 2021	2021	Côte d'Ivoire	Logging	Patch	Rainforest	Composition	Amphibian	Post-harvesting
Leaver et al., 2021	2021	South Africa	Harvesting	Patch	Coastal	Structure	Avian	Management
Bentsi-Enchill et al., 2022	2022	Ghana	Logging	Landscape	Moist forest	Composition	na	Agroforestry
Sullivan et al., 2022	2022	Gabon	Logging	Patch	Tropical forest	Structure	na	Further research
Zebaze et al., 2022	2022	Cameroon	Degradation	Landscape	Tropical forest	Composition	na	none
Kung'u et al., 2023	2023	Kenya	Harvesting	Landscape	Tropical forest	Structure	Athropods	Maintainance
Bitariho et al., 2023	2023	Uganda	Anthropogenic	Patch	Afromontane	Composition	na	Revenues
Esaete et al., 2023	2023	Uganda	Cultivation	Landscape	Deciduous	Composition	na	Further research

CHAPTER 3

Response of bird taxonomic and functional diversity to forest local and landscape characteristics in selected Southern Mistbelt Forests in KwaZulu-Natal, South Africa

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Running header: Avian response to forest categorical disturbance

3.1 Abstract

Forest ecosystems are under threat from anthropogenic activities, including land use change, agricultural conversion and fragmentation. The severe impact of forest disturbances affects the forest communities and, in turn, their important role in ecosystem health and function. We assessed the response of bird taxonomic and functional diversity to structural complexity, heterogeneity, and categorical disturbance in three Southern Mistbelt Forest patches in KwaZulu-Natal, South Africa, in 2024. We used the radius point count to quantify bird species in each forest patch. We used bird functional traits to calculate two functional diversity indices, namely functional richness and functional evenness. Structural complexity and heterogeneity positively influenced species richness and functional diversity for bird communities, specialists, and generalists, while disturbance had a negative impact. However, the functional richness and species richness for generalists and specialists decreased from lower to highly disturbed patches. The results for functional evenness were similar to functional richness, except for generalist functional evenness, which responded positively to the intermediate disturbance hypothesis. Our results demonstrated the importance of recovering patches as an alternative for bird species while primary patches are continually disturbed. The presence of specialist species, including the Bush Blackcap (*Lioptilus nigricapillus*) and Olive Bushshrike (*Telophorus olivaceus*) in disturbed patches, highlights the potential these patches have avian community conservation with ongoing anthropogenic impacts. Intact forest patches require management to prevent anthropogenic disturbances as they are important for endangered and vulnerable species, including Southern Ground Hornbill (*Bucorvus leadbeateri*), Cape Parrots (*Poicephalus robustus*), Bush Blackcap (*Lioptilus nigricapillus*), etc. Microhabitat and landscape characteristics are important in understanding the forest systems and how they shape the avian community. For conservation purposes, constant monitoring of secondary forests is important to assess their recovery and importance as a possible biodiversity hotspot.

Keywords: Forest ecosystem; Structural complexity; Heterogeneity; Functional traits; Ecological role.

3.2 Introduction

Forest ecosystems continue to be threatened by anthropogenic activities globally (Senior et al., 2018; Ehlers Smith et al., 2018a, b; Senf and Seidl, 2020; Mestre et al., 2020; DeArmond et al., 2023). Land use change, agriculture conversion, and fragmentation are the major cited forest degradation that results in habitat loss and affects the distribution of forest communities (Fahrig, 2003; Ferraz et al., 2007; Bełcik et al., 2020; Bentsi-Enchill et al., 2022). Forest fragmentation reduces habitat connectivity, resulting in smaller discontinued patches (Fahrig, 1997; 2003; Bełcik et al., 2020; Ngcobo et al., 2022). Habitat structure and composition are sensitive to these disturbances and may alter the complexity and promote homogeneity (Ferraz et al., 2007; Maseko et al., 2019; Anderle et al., 2022). Forest ecosystems support a variety of species communities as the primary habitat. Due to complexity, the forest fauna is diverse, from small insects to large mammals (see Ross et al., 2018; Kpan et al., 2021; Leaver et al., 2021; Aggarwal et al., 2023; Sosibo et al., 2024). The existence of forest fauna greatly contributes to the functioning of the forest ecosystem as they hold different ecological roles. Researchers have explored the use of forest fauna to understand the forest's functioning and health (Brodie et al., 2014; Mestre et al., 2020). However, the avifaunal component has been the most widely used forest fauna amongst others (see Ferraz et al., 2007; Caves et al., 2013; Mestre et al., 2020; Sarmiento-Garavito et al., 2022; Weeks et al., 2023).

Avian communities have complex and well-described functional ecological traits (Aleixo, 1999; Bryce et al., 2002; Clavel et al., 2011). They are highly mobile, reflected in their distribution range and patch selection (Ehlers Smith et al., 2019). Avian functional traits are important as they correlate with ecosystem functions and can be used as indicators of forest ecosystem health (Bryce et al., 2002; Ehlers Smith et al., 2017a; Lindbladh et al., 2020). Their sensitivity to habitat change has allowed for early predictions of disturbance magnitude and possible implication avenues (Mestre et al., 2020; Anderle et al., 2022). In addition to being habitat indicators, avian communities play an important role in forest ecosystems, including seed dispersal and pollination and can be used as a biological means for pest control (Sekercioglu, 2006; Bitani and Downs, 2022). They inhabit different vertical strata (including ground, understorey, and canopy) and have different diet requirements (insectivorous, granivorous, frugivorous, etc.), providing easy early anticipation of ecosystem health (Bae et al., 2018; Gumede et al., 2022; Bitani et al., 2024). As such, their taxonomic and functional diversity changes as a result of environmental filters in terms of generalist and specialist habitat specificity (Clavel et al., 2011; Colyn et al., 2020; Morena et al., 2024).

Avian taxonomic diversity has been widely used in forest bird research (Gregory and van Strien, 2010; Jankowski et al., 2013; Bae et al., 2018; Leaver et al., 2019a, b). However, taxonomic diversity alone may not reflect on the ecological functions of species and how they play a role in ecosystem functioning (Sarmiento-Garavito et al., 2022). They mainly focus on species abundance and richness and exclude trait-based ecological roles (Morena et al., 2024). Thus, taxonomic diversity (abundance and richness) may be misleading as a result of ecosystems sharing similar attributes (Melo et al., 2024). Meanwhile, functional diversity provides a trait-level link between the species' function and the ecological role in ecosystem functioning (Sekercioglu, 2006; Murray et al., 2017; Mestre et al., 2020). Consequently, incorporating function diversity is more important to understanding the trait-based ecological role to inform conservation and management approaches (Bełcik et al., 2020; Bitani et al., 2023a).

Avian diversity is affected at different spatial scales, reflecting the importance of considering a multiscale approach to study their ecological roles in forest ecosystems (Mao et al., 2023). Local and landscape characteristics are the two determinants of forest faunal diversity and habitat use (Curzel et al., 2021). The habitat covariates and the environment act as filters for species occupancy (Maseko et al., 2017). For example, in South African Indian Coastal Forests and Southern Mistblet Forests, the occupancy of Lemon Dove (*Columba larvata*) was influenced by the cover (grass and canopy) and tree species richness (Ehlers Smith et al., 2017b; Bitani et al., 2023b). Broadly, microhabitat is defined by structural complexity and heterogeneity as strongly influential in the diversity of avian communities (Stirnemann et al., 2015; Maseko et al., 2019; Gumede et al., 2022). In research, structural complexity and heterogeneity have been widely used to understand the extent of disturbances in forest communities across the globe (see Watson et al., 2003; Ehlers Smith et al., 2015; 2017a; Murray et al., 2017; Mestre et al., 2020; Anderle et al., 2022). Briefly, high structural complexity and heterogeneity have been linked with greater avian diversity and the provision of important ecosystem services (Maseko et al., 2019; Curzel et al., 2021; Morena et al., 2024). Meanwhile, the disturbances, adjacent matrix, and patch isolation contribute to landscape characteristics filters that shift the habitat structure and avian communities (Ferraz et al., 2007; Ehlers Smith et al., 2019; Melo et al., 2024).

In South Africa, the indigenous forests occupy the smallest land space (King, 1941; Mucina et al., 2006). They are naturally fragmented and occur in relatively small, disconnected patches (Eeley et al., 1999; Lawes et al., 2004; Adie et al., 2013). However, they play a vital role in the ecosystem functioning and as a hotspot for a great variety of species, including endangered species (Lewis et al., 2015). In KwaZulu-Natal, indigenous forests are in remote areas near the local communities (Lawes et al., 2007a, b). They serve and support human livelihoods through subsistence (Shackleton et al., 2007; Constant and Taylor, 2020). Nevertheless, Southern Mistbelt Forests are largely under threat by anthropogenic activities, highlighting the need for management and conservation considering their role in the ecosystem and human livelihoods (Mucina and Rutherford, 2006; Wilson et al., 2017; Sosibo et al., 2024). Thus, the Southern Mistbelt Forests in KwaZulu-Natal can serve as an important ecosystem for studying the magnitude of disturbance and its impact on biodiversity.

Our study investigated bird taxonomic and function diversity responses to local and landscape characteristics. We assessed how structural complexity, heterogeneity, and categorical disturbances influenced (1) species richness and abundance, and (2) functional richness and evenness. We tested the disturbance hypothesis, which predicts high species diversity in the intermediate, compared with low and high disturbance (Bongers et al., 2009). We predicted (a) high bird species richness in a relatively intact forest, (b) that disturbance would negatively influence functional diversity, and (c) that specialists would be affected by disturbance while generalists would remain unaffected.

3.3 Methods

3.3.1 Study areas

The Southern Mistbelt Forests are temperate forests nested in a montane grassland archipelago in KwaZulu-Natal (Robertson and Lawes, 2005; Adie et al., 2013). Mistbelt Forests are distributed between 1000 and 1600 m a.s.l (Schulze, 2007). The region receives between 724-1181 mm of rainfall, mostly in summer (November to March). It is characterised by warm temperatures with mean temperatures of 19°C and 10°C in the hot summer and cold winter, respectively (Mucina and Rutherford, 2006; Schulze, 2007). They are characterised by steep south-facing slopes with deep river valleys dominated by *Afrocarpus/Podocarpus* spp. (Weathered and Lawes, 2005; Adie et al., 2013). The forests are characterised by discontinued fragmented patches with a size range over 500 ha but usually occur in smaller fragments of approximately 2.6 ha (Adie et al., 2013). They have been subjected to historical logging during colonisation in the 1800s which contributed to fewer relatively intact patches (Lawes et al., 2007a).

We conducted our study in Mzimkhulu (30.2638° S, 29.9381° E) and Creighton (29.8775° S, 29.8815° E) in southern KwaZulu-Natal, South Africa (Figure 3.1). We sampled three Southern Mistbelt Forests (Umgano, Mikhanzeni, KwaYili) that were subjected to different disturbance intensities (Figure 3.1). We categorised them as low disturbance (Umgano), medium disturbance (KwaYili), and high disturbance (Mikhanzeni) patches. The selection of the disturbance gradient was based on the condition of the forest and how it was used by nearby communities. Umgano Forest (locally known as Maxhegu) is a relatively intact primary forest patch dominated by *Afrocarpus*/ *Podocarpus* spp. (Fisher et al., 2024). The forest has not been subjected to any historical logging or disturbances during colonisation. KwaYili State Forest is a secondary thicket-dominated forest patch. There are traces of disturbance (Nomtshongwana, 1999), such as walking routes that lead to the forest interior with pioneers and lianas (pers. obs.). Local community members have cut down some *Afrocarpus/Podocarpus* spp. and numerous vertical dead trees. The patch is still recovering, but the disturbances from livestock grazing and exploitation may delay the recovery process (Nomtshongwana, 1999; pers. obs.). Meanwhile, Mikhanzeni Forest (locally known as Mashisa) is highly disturbed, containing roads leading inside the forest interior. The forest is highly invaded by the invasive species *Solanum mauritianum* (pers. obs.). The forest is characterised by discontinuous patches because of the plantation that surrounds the patch and is highly concentrated in other parts of the interior (pers. obs.).

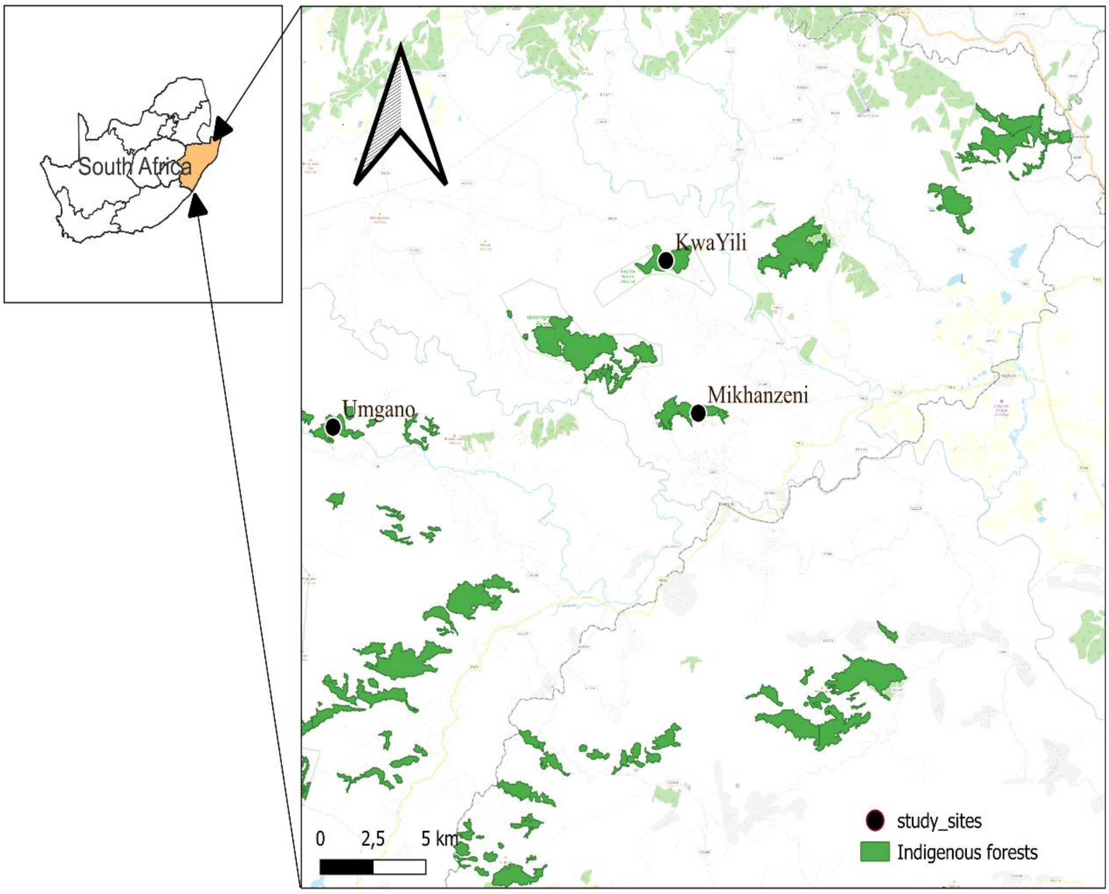

Figure 3.1: Map showing the location of the indigenous forests we sampled in southern KwaZulu-Natal, South Africa. (Note: KwaZulu-Natal is shown as orange in the insert).

3.3.2 Bird surveys

We conducted bird surveys in the breeding (January - February) and non-breeding seasons (June - July) of 2024. At each patch, we conducted a fixed radius point count with points separated apart by 200 m and recorded all the bird species audible and visualised within a distance of 100 m (Maseko et al., 2019; Ehlers Smith et al., 2019; Gumede et al., 2022; Bitani et al., 2023b). Depending on the patch size, the number of points varied in each patch with 18, 13, and 11 point counts for Umgano, Mikhanzeni, and KwaYili, respectively. The surveys were done during the morning for 3 h after sunrise, where 10 min was spent on each point; therefore, nocturnal birds were excluded (Bibby et al., 2000). Any species that could not be confidently identified was not recorded. We used sound recording (mobile device) for complicated calls for later identification while keeping track of the point where the sound was recorded. The same points were used to survey for both seasons. The data for both seasons was pooled into one dataset to be the total bird community for each patch. We formulated a functional trait matrix for every bird species we recorded (Supplementary Information Table S3.1; Ehlers Smith et al., 2018a). We included the body mass, dietary guild (carnivory, frugivory, nectarivory, granivory or insectivory), feeding strategy (harvest, terrestrial probe, arboreal probe, glean, perch and swoop, or various), nesting strategy (ground, ball or cup, cavity, or platform), and habitat specificity (generalists or specialists) (Supplementary Information Table S3.1; Ehlers Smith et al., 2018a).

3.3.3 Vegetation sampling

We created a 20 m radius at each point used for the bird survey and separated it into four quarters using a tape measure. We recorded the average grass, herbaceous, scrub, and maximum tree height each quarter (Gumede et al., 2022). We estimated the percentage cover for bare ground, leaf litter, short and tall grass, short and tall herbaceous plants, and scrubs/woody plants (<2 m) (Bitani et al., 2023b). We estimated the tree heights using five height classes (2-5 m, 6-10 m, 11-15 m, 16-20 m, 20+ m) (Bibby et al., 2000; Ehlers Smith et al., 2017a, b, c). In addition, we collected the number of dead trees observed in each quarter. We assessed structural complexity and heterogeneity for each point using the Shannon-Wiener Diversity Index (SWDI) formula:

$H = - \sum pi \ln (pi)$, where:

Pi represents the total foliage proportion in the *ith* layer of the chosen horizontal layer (Bibby et al., 2000). For structural complexity, we used the averaged percentage cover, and we used vegetation classes (grass, herbaceous, scrubs, and trees) for heterogeneity (Bitani et al., 2023b). At each patch, we averaged the structural complexity and heterogeneity to obtain the complexity and heterogeneity of each patch.

3.3.4 Data analyses

As we were interested at a landscape level, we ran all of our analyses at the landscape level instead of the point level. We created three matrices, namely abundance, presence and absence, and trait matrix, to calculate functional diversity indices (functional richness (FRic) and functional evenness (FEve)). Using the function 'dbFD' as per Gower functional dissimilarity to calculate the functional indices of each forest patch (Laliberté et al., 2014). We ran generalised linear models (GLMs) to determine the effect of local (structural complexity and heterogeneity) and landscape (categorical disturbance) characteristics on bird FRic and FEve (Table 3.1). Before fitting the models, we checked for correlation. Although there was a strong correlation between structural complexity and heterogeneity (r = 0.94), we kept the covariates to maximise covariate samples, given our objective to assess structural complexity and heterogeneity (Ehlers Smith et al., 2017c). In R (R Core Team, 2025), we standardised our predictor variables because of the differences in units, allowing us to compare each variable's relative effect. We used the z scores to standardise the data. We ran a Spearman correlation because our data were not normally distributed, and we checked for overdispersion using package performance. As a result of overdispersion, we fitted for a negative binomial error distribution using package 'MASS'. We fitted a global model including all the predictor variables against each functional index. We rated the importance of our models using the Akaike Information Criterion (AIC). We selected the top model using ΔAIC, where models with ΔAIC<2 are considered the top models (Burnham and Anderson, 2004). For our data, we also tested the disturbance hypothesis, which predicts high species diversity in the intermediate disturbance (Bongers et al., 2009). The hypothesis was tested for taxonomic and functional diversity across all bird assemblages.

3.4 Results

3.4.1 Taxonomic diversity

We conducted a total of 42 fixed-point counts and recorded a total of 662 bird individuals representing 66 species and 21 families (Supplementary Information Table S3.1). Three of these bird species were classified as endangered, vulnerable, and nearly threatened, such as the Bush Blackcap (*Lioptilus nigricapillus*), the Southern Ground Hornbill (*Bucorvus leadbeateri*), and the Cape Parrot (*Poicephalus robustus*) (Supplementary Information Table S3.1). The bird community's total abundance showed a variation across sites, with about 45% (n = 293) individuals recorded in a low disturbance patch while 22% (n = 149) and 33% (n = 220) were recorded in the medium and highly disturbed patches, respectively (Supplementary Information Table S3.2). The abundance of birds' habitat specificity differed according to generalist and specialist bird species. Of the total individuals recorded, 38% (n = 249) were specialist species, while 62% (n = 415) were generalist species (Supplementary Information Table S3.3). The variation across forests was also noted in generalist and specialist species. More specialists (n = 135) were recorded in a low disturbed patch compared with medium (n = 53) and highly (n = 60) disturbed patches (Supplementary Information Table S3.3).

The species richness varied across disturbance levels. The categorical disturbance had a non-significant negative influence on species richness ($p = 0.132$), while structural complexity ($p = 0.008$) heterogeneity ($p = 0.01$) had a significant positive influence (Figure 3.2). Similarly, trends were observed with specialists and generalists ($p < 0.05$; Figure 3.3). The total richness for the bird community was high (n = 54) in a low disturbance patch and varied for the medium (n = 31) and highly (n = 38) disturbed forest patches.

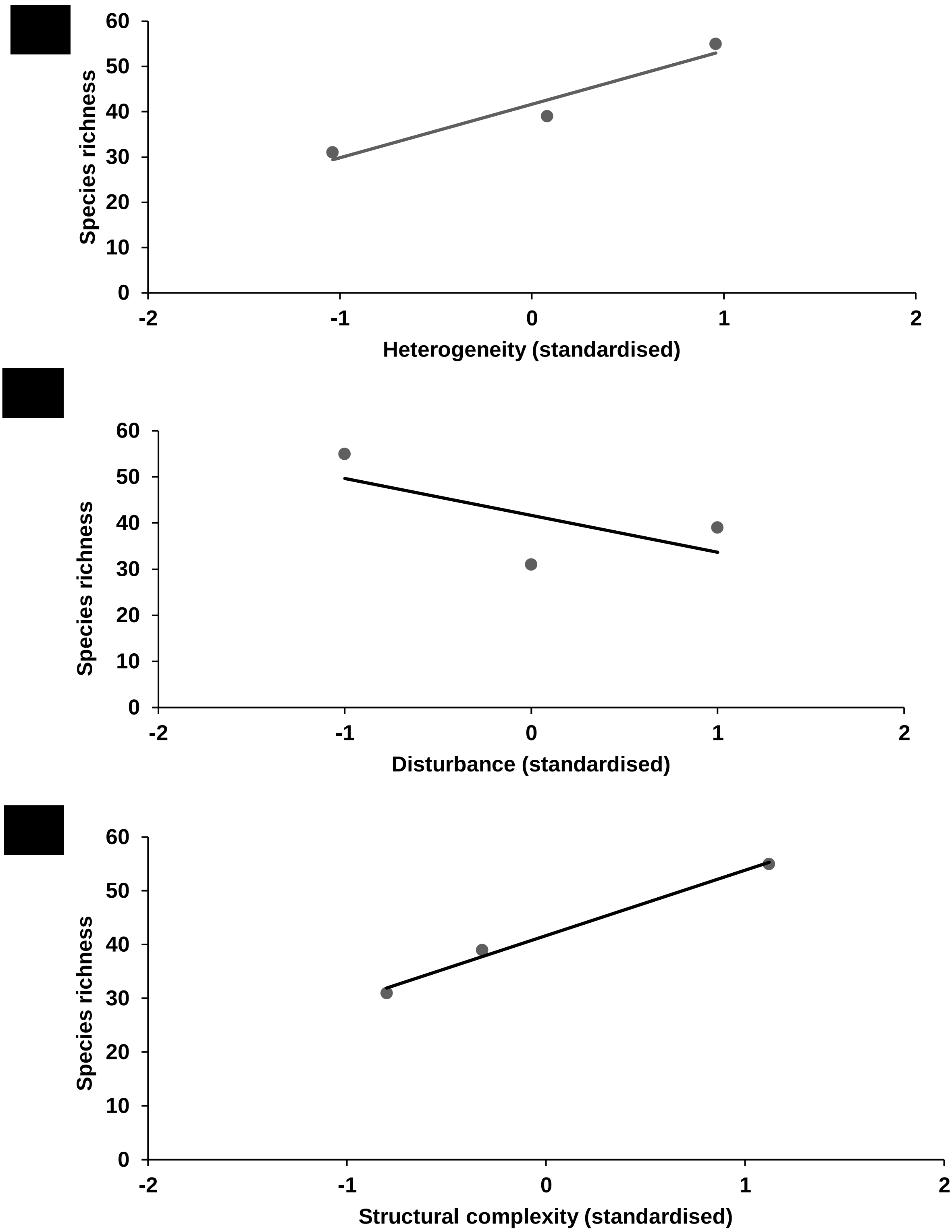

Figure 3.2: The relationship between bird species richness and (a) heterogeneity , (b) categorical disturbance, and (c) structural complexity in three Southern Mistbelt Forests of differing disturbance levels.

Similarly, we found the high species richness in a lower disturbed patch for specialists and generalists (Figure 3.3). In addition to the dominant species in the community (i.e. African Olive Pigeon (*Columba arquatrix*), Sombre Greenbul (*Andropadus importunes*), and Southern Boubou (*Laniarius ferrugineus*), other bird species had specific patch preferences. Twenty-one species (31.3% of total bird species) were found in the low disturbance patch only, including the Olive Bushshrike (*Telophorus olivaceus*), Southern Ground Hornbill, Orange Ground Thrush (*Geokichla gurneyi*), and others (Supplementary Information Table S3.2). Only three species were found in the medium disturbed patch, including the White-bellied Sunbird (*Cinnyris talatala*), and the Yellow-bellied Greenbul (*Chlorocichla flaviventris*) (Supplementary Information Table S3.2). Only five species were found in the highly disturbed patch, including the Golden-tailed Woodpecker (*Campethera abingoni*), Burchell's Coucal (*Centropus burchellii*), and the Gorgeous Bushshrike (*Telophorus quadricolor*) (Supplementary Information Table S3.2).

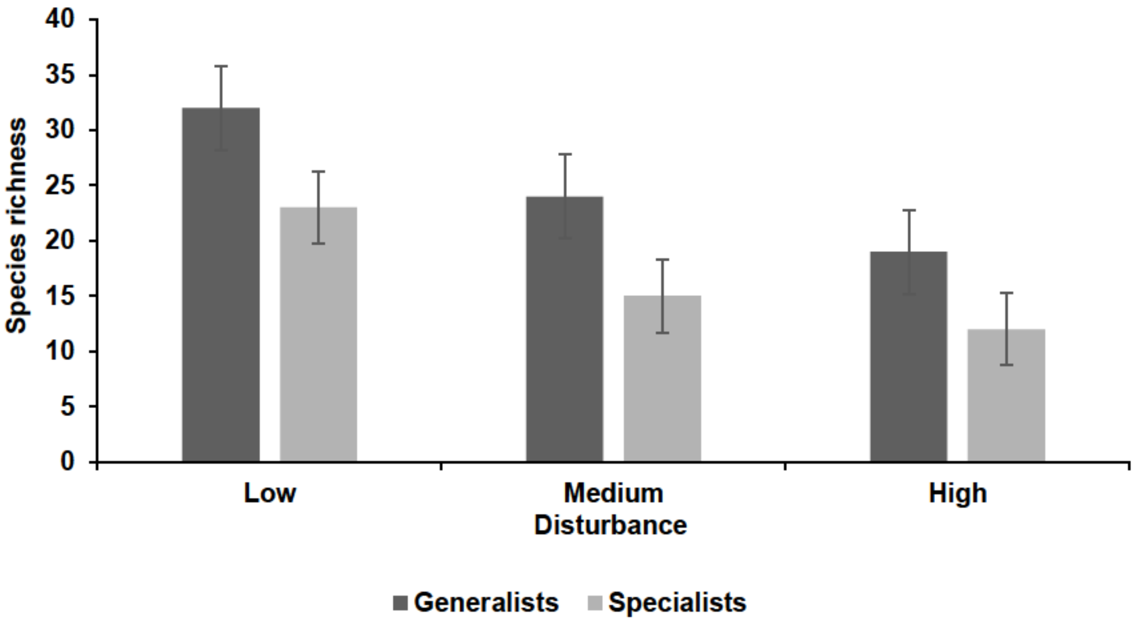

Figure 3.3: The response of taxonomic species richness with different levels of disturbance in three Southern Mistbelt Forests.

3.4.2 Functional diversity

The characteristics shown by the models in Table 3.1 represent the influence that the predictor variables (disturbance, structural complexity, heterogeneity) had on the functional indices (FRic, FEve). Across disturbance categories, the functional richness of the bird community decreased with increasing disturbance (Figure 3.4). The functional richness was negatively influenced by categorical disturbance. In contrast, it was positively influenced by structural complexity and heterogeneity (Table 3.1). The structural complexity and heterogeneity had a non-significant positive influence on generalists ($p = 0.25$) and specialists ($p = 0.09$), respectively. The positive association resulted in high functional richness in the less disturbed patch, thereafter increased functional richness with disturbance from intermediate to high levels (Table 3.1; Figure 3.4). Although FRic for the bird community was influenced by categorical disturbance, it was higher than that of generalists and specialists, respectively.

Table 3.1: Generalised Linear Models (GLMs) output for top models to predict the effects of categorical disturbances (D), structural complexity (SC), and heterogeneity (HI) on functional richness (FRic) and functional evenness (FEve) of specialists, generalists, and birds community. The models are ranked based on the corrected Akaike Information Criterion (AIC). Models with ΔAIC< 2 are presented.

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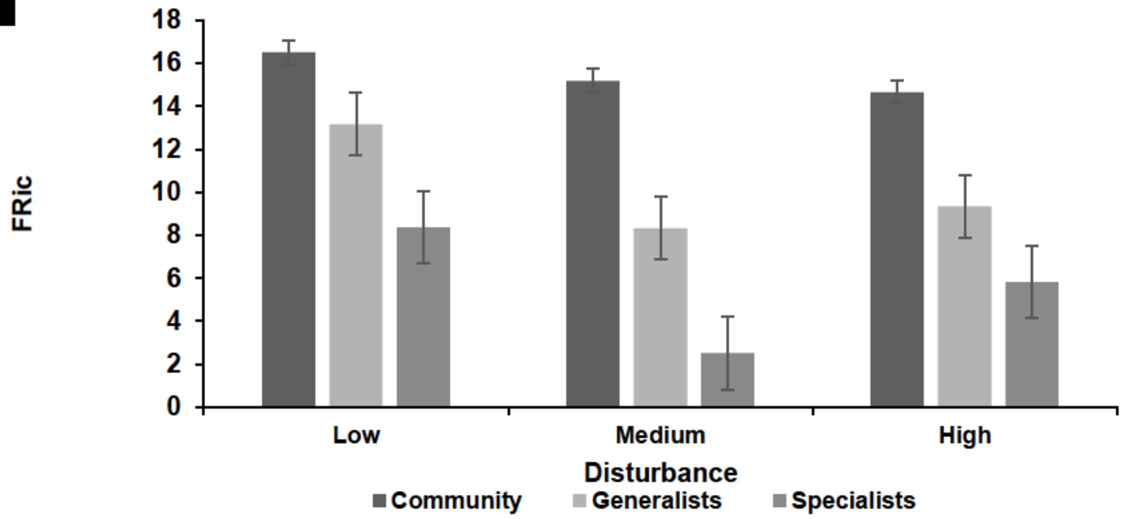
Functional traits	**Response variables**	**Model**	**df**	**AIC**	**ΔAIC**	**Log-likelihood**	**P value**
FRic	Community	D (-) + SC (+) + HI (+)	2	17.91	0.00	-13.79	0.001
		D (-)	1	19.73	1.82	-13.73	0.857
		SC (+)	1	19.73	1.82	-13.73	0.840
		HI (+)	1	19.77	1.86	-13.77	0.863
	Specialists	HI (+)	1	16.53	0.00	-10.53	0.087
		SC (+)	1	17.17	0.64	-11.17	0.175
	Generalists	SC (+)	1	18.54	0.00	-12.54	0.250
		HI (+)	1	18.72	0.18	-12.72	0.203
		D (-)	1	19.23	0.59	-13.13	0.274
FEve	Community	D (-)	1	9.96	0.00	-3.96	0.948
		HI (+)	1	9.97	0.01	-3.37	0.981
	Specialists	HI (+)	1	9.75	0.00	-3.75	0.946
		D (+)	1	9.76	0.01	-3.76	0.986
		SC (+)	1	9.76	0.03	-3.76	0.957
	Generalists	SC (+)	1	10.30	0.00	-4.36	0.880

As observed with FRic, there was also a variation in FEve. Generalists had the highest FEve across all three disturbance levels (Figure 3.4). Similar to FRic, structural complexity had a non-significant positive influence on FEve for generalists ($p = 0.89$; Table 3.1). The functional evenness of generalist species is the only functional index that showed a positive response to disturbance hypotheses (Figure 3.4). As per the predictions, the functional richness of generalists was higher at intermediate disturbance than at lower and higher disturbance levels (Figure 3.4). Meanwhile, the bird community and specialists' functional evenness were explained by categorical disturbances and heterogeneity, respectively (Table 3.1). The categorical disturbance had a non-significant negative influence ($p = 0.9$) on FEve for the bird community, while heterogeneity had a non-significant positive influence ($p = 0.95$) on FEve for specialists (Table 3.1). Furthermore, the bird community and specialists showed similar trends (i.e. the functional evenness decreased with increasing disturbance from low to intermediate, and thereafter, decreased to a high disturbance level). For our data, only the functional evenness of generalists conformed to the Intermediate Disturbance Hypothesis (Figure 3.4).

[redacted]



[redacted]

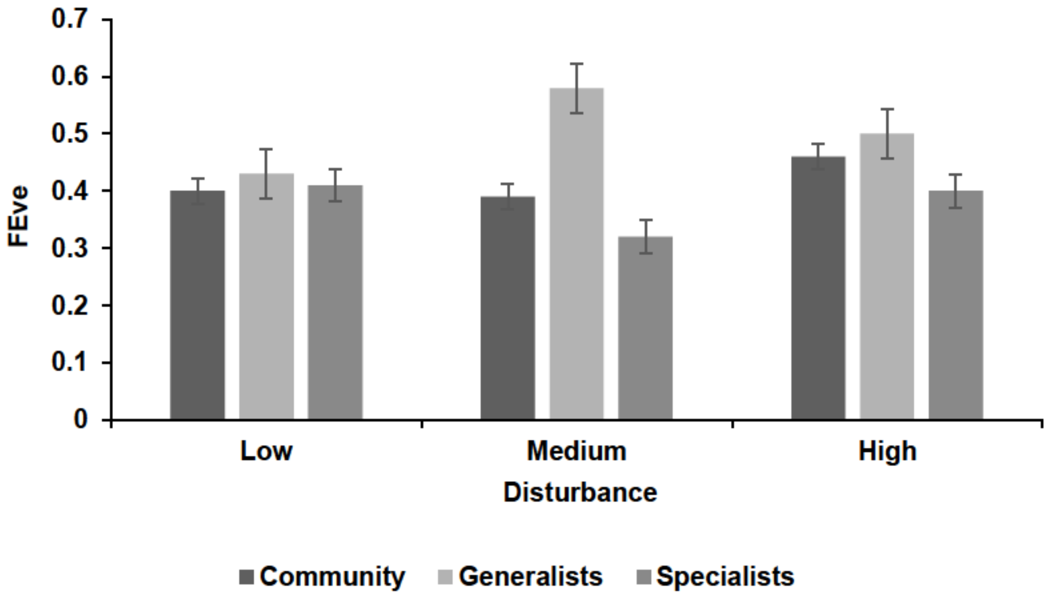


Figure 3.4: The response of (a) bird functional richness and (b) evenness to categorical disturbance in Southern Mistbelt Forests in KwaZulu-Natal.

3.5 Discussion

Our study outlined the importance of local and landscape characteristics as determinants of functional trait response and habitat preferences. We assessed how taxonomic and functional diversity respond to these characteristics. Taxonomic richness mainly informed on the presence of species in patches and allowed us to identify the distribution of bird communities to species level and their abundance. This highlighted the necessity of taxonomic richness in providing informative measures for management and conservation (Bae et al., 2018; Maseko et al., 2019; Bełcik et al., 2020; Mao et al., 2023). In addition, we also considered functional diversity to inform how these species use and select habitat patches (Mao et al., 2023). Functional response is important to understand forest disturbance through the assessment of different diversity indices at once (Bitani et al., 2024). The response of bird species varied across forest disturbance levels. As expected, the species richness and abundance decreased with increased disturbance from low to intermediate disturbance. These results are supported by Mao et al. (2023), who found high species richness in a patch with low human disturbance in China. The reason for this is the decreased heterogeneity and structural complexity, which reduces resource availability and avian community (Watson et al., 2003; Jankowski et al., 2013; Stirnemann et al., 2015; Maseko et al., 2019; Morena et al., 2024). Similar findings were reported in southern Australia, where richness increased with patch scale covariates (Stirnemann et al., 2015). A slight difference was noted in the response from intermediate to high disturbance gradient. This is attributed to the increased heterogeneity and complexity from intermediate to highly disturbed patches, as vegetation structure is an important environmental predictor (Jankowski et al., 2013; Ehlers Smith et al., 2021; Melo et al., 2024). A study in urban landscape mosaic highlighted the overlapping species and habitat characteristics between the lower and highly disturbed patches (Maseko et al., 2019).

The disturbed habitat in the Mistbelt Forests has an ability to recover and have similar structural covariates with the primary forest over time. However, the Mistbelt Forests in the Karlkloof have not recovered since the 1940s, which resulted in the local extinction of Cape Parrots (Bitani et al., 2023a). This may result from high disturbances experienced during colonisation in the 1800s up to the 1940s as well as fire invasions (King et al., 1941; Rycroft, 1944). Also, specialist species may have moved because of the changes in ecological niches or been displaced by generalist species, given the high abundance and richness of generalists (Bełcik et al., 2020; Bitani et al., 2024). This may lead to local extinction and reduce community heterogeneity (Sekercioуglu, 2012). While species richness and abundance may disregard sensitive species to disturbance and the ecological role of these species, functional diversity (FRic and FEve) in our assessment enhances the validity of our findings. Therefore, in contrast to taxonomic diversity, the functional richness decreased with increased disturbance across the three levels of disturbances (low, mid, and high). This outlines the need to incorporate both taxonomic and functional diversity when assessing birds diversity (Bae et al., 2018).

Functional richness responses of bird communities were strongly influenced by categorical disturbances, structural complexity, and heterogeneity. Considering a significant negative correlation between patch and landscape characteristics, increasing disturbance gradient decreases the structural complexity and heterogeneity. However, there was an exception where the highly disturbed patch had increased structural complexity and heterogeneity. Other researchers have reported decreasing complexity and heterogeneity because of increasing disturbances (Stirnemann et al., 2015; Ehlers Smith et al., 2018a; Mao et al., 2023; Bitani et al., 2024). The functional richness of the bird community positively responded to complexity and heterogeneity while responding negatively to categorical disturbance (see Table 3.1). Similar trends were observed in terms of functional evenness for the bird communities (Table 3.1). In contrast, the functional richness of generalists and specialists responded positively to structural complexity and heterogeneity, respectively (Table 3.1). These covariates are essential for birds' microhabitat requirement, and they provide various resources required by species with low distribution range (Serkeciouglu, 2012; Stirnemann et al., 2015). Interestingly, functional richness for specialists and generalists responded positively to a highly disturbed patch. Generally, generalists can persist in modified habitats as they are not entirely sensitive to changes in ecological niches (Edwards et al., 2014; Bitani et al., 2020; Bełcik et al., 2020; Ngcobo et al., 2022). The occurrence of specialist species in disturbed patches may indicate the availability of specific ecological niches that specialist species require to survive and persist in these patches (Rea et al., 2023). The functional evenness for specialists showed a similar response to local scale covariates (structural complexity and heterogeneity), except for generalists which showed a positive response to the intermediate disturbance hypothesis.

The diversity in functional traits allows for different and unique ecological roles (Hamer et al., 2015; Gumede et al., 2022). For example, the bird species in this present study varied according to their diet (insectivores, frugivores, granivores, etc.), feeding (gleaning, hawk, harvest, etc.), and nesting type (ground, ball or cup, cavity, etc.). This highlights the importance of different ecological roles in the ecosystem, including dispersal, biocontrol, and stabilising the ecosystem (Bitani et al., 2022; Mao et al., 2023). Insectivorous species were dominant, and the majority of these species were using a gleaning strategy for feeding. In terms of nesting strategy, they preferred the ball or cup nesting strategy (Supplementary Information Table S3.3). This highlights the importance of patch scale covariates (leaf litter, grass cover, canopy cover, tree species richness, etc.) on the response of birds ecological traits to different level of strata (see Stirnemann et al., 2015; Hamer et al., 2015; Bitani et al., 2023a). Therefore, considering the importance of maintaining diversity and conservation in Mistbelt Forests, we strongly recommend forest research to incorporate ecological traits to study forest disturbances.

The disturbance gradient influenced patch selection, which was determined by the sensitivity and vulnerability to patch disturbance. The endangered Southern Ground Hornbill only selected patches with high structural complexity and heterogeneity (Supplementary Information Table S3.2). Although not a forest specialist, this highlights that relatively intact patches are crucial for the management and conservation of vulnerable species (Bitani et al., 2023a). The vulnerable Bush Blackcap also showed a preference for the relatively intact patch. As expected, these are forest specialists and have a specific habitat requirement (e.g., presence in Umgano Forest). The selection of lower disturbed patches may be explained by their ability to provide high-quality resources (Bae et al., 2018; Bełcik et al., 2020). In China, urban birds showed a preference for lower disturbed patches because of high resource availability (Mao et al., 2023). In contrast, the endangered Cape Parrot was found in the three patches and did not show any preference in patch selection. This may be explained by the fact that they mainly select patches dominated by *Podocarpus/ Afrocarpus*, and therefore, the forest state might not be a filter (Bitani et al., 2023a). However, it was more abundant in a relatively intact patch (lower disturbed). Similarly, Rea et al. (2023) reported that logging did not have an impact on the detectability of the Cape Parrots in the Amathole region in the Eastern Cape, South Africa. The presence of Cape Parrots in disturbed patches may be attributed to the availability of resources such as dead trees (snags), which are crucial for their nesting as a secondary cavity nester (Downs and Symes, 2004; Downs, 2005; Jankowski et al., 2015; Rea et al., 2023). This highlights the importance of disturbed patches as having a potential for species conservation. Therefore, disturbed patches need to be assessed more often and included in conservation and management measures (Maseko et al., 2019; Bitani et al., 2024).

3.6 Conclusions

We used local (structural complexity and heterogeneity) and landscape (categorical disturbance) characteristics to assess the response of bird taxonomic and functional diversity. We are aware of other important covariates (e.g., patch size and tree species composition) that may have impacted the response of bird communities to these characteristics. However, we neglected other covariates to avoid multicollinearity because of sample size (forest patches) and patch similarities (Bae et al., 2018). Therefore, we recommend the inclusion of other covariates when dealing with larger sampling sizes. Integrating taxonomic and functional diversity is important in forest research. While taxonomic diversity provides insight into species distribution, functional diversity informs one of the ecological roles of species. Structural complexity and heterogeneity are important covariates for resource requirements. Bird communities, especially specialist species, are sensitive to altered patches because of reduced complexity and heterogeneity, while generalists are not affected. The replacement of specialists by generalists because of severe disturbance poses an extinction threat and increases the homogeneity of forest communities. There was a positive correlation between the functional indices (FRic and FEve) and patch covariates, except for the case where FEve responded positively to disturbance prediction. The microhabitat covariates are essential for the support of bird communities, including the endangered and vulnerable species, as they prefer structurally complex patches with high heterogeneity. However, it is important to note that disturbed forests also have the potential to support a variety of sensitive species, including Cape Parrots. Therefore, protecting the intact forest patches in Mistbelt Forests is crucial, while disturbed forests need to be monitored regularly and also conserved.

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3.9 Supplementary Information

Supplementary Information Table S3.1: Bird species recorded in three Mistbelt Forest patches in southern KwaZulu-Natal, South Africa

Family	Scientific name	Forests Umgano (n)	Mikhanzeni (n)	KwaYili (n)
Accipitridae	*Milvus aegyptius*	1	0	0
Bucorvidae	*Bucorvus leadbeateri*[E;V]	1	0	0
Campephagidae	*Coracina caesia*	11	6	0
Campephagidae	*Campephaga flava*	0	1	0
Caprimulgidae	*Caprimulgus pectoralis*	2	2	0
Cisticolidae	*Camaroptera brachyura*	17	11	9
Cisticolidae	*Prinia hypoxantha*	2	0	1
Cisticolidae	*Apalis thoracica*	16	4	4
Cisticolidae	*Cisticola aberrans*	3	0	0
Cisticolidae	*Prinia subflava*	0	1	1
Columbidae	*Columba arquatrix*	4	20	16
Columbidae	*Aplopelia larvata*	1	0	0
Columbidae	*Streptopelia semitorquata*	9	17	5
Columbidae	*Streptopelia capicola*	3	14	3
Corvidae	*Corvus capensis*	0	3	2
Cuculidae	*Cuculus solitarius*	17	2	5
Cuculidae	*Chrysococcyx klaas*	3	0	0
Cuculidae	*Chrysococcyx cupreus*	1	0	1
Cuculidae	*Cuculus clamosus*	0	2	0
Cuculidae	*Centropus burchellii*	0	1	0
Dicruridae	*Dicrurus adsimilis*	11	2	2
Estrildidae	*Coccopygia melanotis*	2	0	0
Indicatoridae	*Indicator indicator*	1	0	0
Indicatoridae	*Indicator variegatus*	2	0	0
Locustellidae	*Bradypterus barratti*	1	1	0
Lybiidae	*Lybius torquatus*	1	0	0
Lybiidae	*Pogoniulus bilineatus*	0	0	2
Lybiidae	*Lybius torquatus*	1	0	0
Malaconotidae	*Chlorophoneus sulfureopectus*	4	0	0
Malaconotidae	*Malaconotus blanchoti*	1	5	3
Malaconotidae	*Chlorophoneus olivaceus*	5	0	5
Malaconotidae	*Tchagra tchagra*	1	2	2
Malaconotidae	*Laniarius ferrugineus*	8	18	15
Malaconotidae	*Telophorus viridis*	0	3	0
Malaconotidae	*Dryoscopus cubla*	1	0	0
Monarchidae	*Trochocercus cyanomelas*	3	1	0
Motacillidae	*Anthus leucophrys*	1	0	0
Muscicapidae	*Cossypha dichroa*	1	1	0
Muscicapidae	*Cossypha caffra*	4	3	2
Muscicapidae	*Pogonocichla stellata*	2	0	0

Musophagidae	*Tauraco corythaix*	4	4	1
Nectariniidae	*Cinnyris chalybeus*	2	2	0
Nectariniidae	*Hedydipna collaris*	2	0	0
Nectariniidae	*Cinnyris talatala*	0	0	1
Oriolidae	*Oriolus larvatus*	7	3	5
Paridae	*Melaniparus niger*	4	4	1
Phasianidae	*Pternistis afer*	1	0	0
Phoeniculidae	*Phoeniculus purpureus*	1	1	0
Picidae	*Campethera abingoni*	0	1	0
Picidae	*Chloropicus namaquus*	0	1	0
Picidae	*Campethera abingoni*	4	0	0
Picidae	*Dendropicos griseocephalus*	2	1	1
Platysteiridae	*Batis capensis*	4	1	3
Ploceidae	*Ploceus ocularis*	1	1	0
Psittacidae	*Poicephalus robustus*[E;V]	27	3	5
Pycnonotidae	*Phyllastrephus terrestris*	9	17	10
Pycnonotidae	*Andropadus importunus*	49	39	31
Pycnonotidae	*Pycnonotus tricolor*	4	8	5
Pycnonotidae	*Chlorocichla flaviventris*	0	0	1
Sarothruridae	*Sarothrura elegans*	7	3	0
Sylviidae	*Lioptilus nigricapillus*[V]	3	1	0
Threskiornithidae	*Bostrychia hagedash*	3	0	0
Turdidae	*Turdus smithi*	1	0	0
Turdidae	*Geokichla gurneyi*	1	0	0
Turdidae	*Turdus olivaceus*	1	0	5
Zosteropidae	*Zosterops virens*	15	10	2

[E] Endangered

[NT] Near-threatened

[V] Vulnerable

Supplementary Information Table S3.2: Presence and absence of bird species in three sampled Mistbelt Forests in southern KwaZulu-Natal, South Africa

Scientific name	Umgano	Mikhanzeni	KwaYili
Andropadus importunus	0	0	1
Anthus leucophrys	0	1	1
Apalis thoracica	1	0	0
Aplopelia larvata	1	1	0
Batis capensis	0	1	0
Bostrychia hagedash	1	0	0
Bradypterus barratti	1	0	0
Bucorvus leadbeateri	1	1	1
Camaroptera brachyura	1	1	1
Campephaga flava	1	1	1
Campethera abingoni	1	1	1
Campethera abingoni	0	1	1
Caprimulgus pectoralis	1	1	1
Centropus burchellii	1	1	1
Chlorocichla flaviventris	1	0	0
Chlorophoneus olivaceus	1	1	0
Chlorophoneus sulfureopectus	1	0	0
Chloropicus namaquus	1	1	0
Chrysococcyx cupreus	1	1	0
Chrysococcyx klaas	1	0	0
Cinnyris chalybeus	1	1	1
Cinnyris talatala	1	0	0
Cisticola aberrans	1	1	1
Coccopygia melanotis	1	0	1
Columba arquatrix	1	0	0
Coracina caesia	1	1	1
Corvus capensis	1	1	1
Cossypha caffra	0	1	1
Cossypha dichroa	1	1	1
Cuculus clamosus	1	0	0
Cuculus solitarius	1	1	1
Dendropicos griseocephalus	0	1	0
Dicrurus adsimilis	1	1	1
Dryoscopus cubla	1	0	0
Geokichla gurneyi	0	0	1
Hedydipna collaris	1	0	0
Indicator indicator	1	0	0
Indicator variegatus	1	1	1
Laniarius ferrugineus	1	1	0
Lioptilus nigricapillus	1	0	0
Lybius torquatus	1	1	0
Lybius torquatus	1	0	0
Malaconotus blanchoti	1	0	1
Melaniparus niger	1	1	1
Milvus aegyptius	1	1	0

Oriolus larvatus	1	0	1
Phoeniculus purpureus	0	1	0
Phyllastrephus terrestris	1	0	0
Ploceus ocularis	1	1	1
Pogoniulus bilineatus	1	0	0
Pogonocichla stellata	1	1	0
Poicephalus robustus	1	1	0
Prinia hypoxantha	1	0	1
Prinia subflava	1	1	1
Pternistis afer	0	1	0
Pycnonotus tricolor	1	0	0
Sarothrura elegans	1	0	0
Streptopelia capicola	1	1	1
Streptopelia semitorquata	1	1	1
Tauraco corythaix	0	1	0
Tchagra tchagra	1	0	0
Telophorus viridis	1	0	0
Trochocercus cyanomelas	0	1	1
Turdus olivaceus	1	1	1
Turdus smithi	0	0	1
Zosterops virens	1	1	0

1 Present

0 Absent

Supplementary Information Table S3.3: Functional traits of bird species collected in the Southern Mistbelt Forests

		Dietary guild						Feeding strategy						Nesting strategy					Habitat specificity	
Scientific name	**Body mass**	**Carnivory**	**Frugivory**	**Omnivory**	**Nectarivory**	**Granivory**	**Insectivory**	**Harvest**	**Terrestrial probe**	**Arboreal probe**	**Glean**	**Hawk**	**Perch and swoop**	**Various**	**Ground**	**Ball or cup**	**Cavity**	**Platform**	**Generalist**	**Specialists**
Andropadus importunus	15	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Anthus leucophrys	9.5	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
Apalis thoracica	26	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Aplopelia larvata	46	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
Batis capensis	80	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	1	0
Bostrychia hagedash	640	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Bradypterus barratti	54	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0
Bucorvus leadbeateri	31.5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0
Camaroptera brachyura	11	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Campephaga flava	31	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0
Campethera abingoni	300	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Campethera abingoni	150	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0
Caprimulgus pectoralis	75	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1

Centropus burchellii	65	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Chlorocichla flaviventris	26	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Chlorophoneus olivaceus	31	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
Chlorophoneus sulfureopectus	3770	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
Chloropicus namaquus	30	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Chrysococcyx cupreus	60	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Chrysococcyx klaas	1250	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0
Cinnyris chalybeus	60	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0
Cinnyris talatala	150	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1
Cisticola aberrans	10.5	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Coccopygia melanotis	33	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Columba arquatrix	27	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Coracina caesia	407	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Corvus capensis	28	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0
Cossypha caffra	15	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	1	0
Cossypha dichroa	47	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0
Cuculus clamosus	78	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Cuculus solitarius	77	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0
Dendropicos griseocephalus	32	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Dicrurus adsimilis	12	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Dryoscopus cubla	50	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0
Geokichla gurneyi	40	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1

Hedydipna collaris	90	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0
Indicator indicator	21	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1
Indicator variegatus	21	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
Laniarius ferrugineus	50	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0
Lioptilus nigricapillus	8	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
Lybius torquatus	640	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0
Lybius torquatus	13	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Malaconotus blanchoti	35	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1
Melaniparus niger	235	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0
Milvus aegyptius	45	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	1
Oriolus larvatus	66	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0
Phoeniculus purpureus	37	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Phyllastrephus terrestris	70	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1
Ploceus ocularis	300	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Pogoniulus bilineatus	76	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	1	0
Pogonocichla stellata	62	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1
Poicephalus robustus	8	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Prinia hypoxantha	10	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Prinia subflava	43.75	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0
Pternistis afer	180	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0
Pycnonotus tricolor	48	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1
Sarothrura elegans	54	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0

Streptopelia capicola	37.3	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0
Streptopelia semitorquata	13.5	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0
Tauraco corythaix	70	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1
Tchagra tchagra	24	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
Telophorus viridis	68	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1
Trochocercus cyanomelas	500	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Turdus olivaceus	45	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1
Turdus smithi	7.75	0	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0
Zosterops virens	10	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1

CHAPTER 4

Perceptions of the importance, value, and role of Southern Mistbelt Forests held by nearby communities in KwaZulu-Natal, South Africa

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Running header: Perceptions of forest use by local communities

4.1 Abstract

Globally, forests are threatened by multiple disturbance factors. These include anthropogenic activities such as deforestation, driven by poverty and rapid population expansion. In eastern South Africa, many rural communities are located near natural forest patches, and if not, are within travelling distance. Therefore, community members rely on forest resources, especially in places like KwaZulu-Natal. We aimed to document people's perceptions and values of their nearby forest. Using structured questionnaires, we surveyed selected communities residing near the indigenous forests in southern KwaZulu-Natal, during 2023-2024, to document (1) their perceptions on the value and use of the forests, (2) the impact of forest disturbance on the nearby community, and (3) the conservation implications. We conducted a total of 360 questionnaires across seven selected rural communities. We used generalised linear mixed models (GLMMs) to assess the effect of different predictor variables on our response variables. Our results showed that forests are highly valuable to these rural communities. Local community members benefit from forest resources such as firewood, traditional medicines, building materials, etc. They use these resources to build houses and fences, treat illness, and generate income through sales. During the dry season, the forests become primarily important for foraging for their livestock, reducing the use of expensive supplements. Understanding people's perceptions is crucial to acknowledge spiritual, cultural, and religious values associated with the forest.

Keywords: Anthropogenic activities; Ecosystem services; Biodiversity; Conservation; Remote areas; Forest modification.

4.2 Introduction

Human-forest interactions have caused a significant increase in forest modification, altering the functioning of the forest ecosystems (Lawes et al., 2007; Shackleton et al., 2013; 2019; Leaver et al., 2019; 2020). Forests are threatened by several disturbance factors, including anthropogenic activities, globally (Guertin, 2003; Menton, 2003; Medina et al., 2009; Lawes et al., 2007; Armenteras et al., 2023; Mujetahid et al., 2023). Hunting and logging in forest patches surrounded by rural communities are the major cited direct and indirect forest disturbance regimes, respectively (Sosibo et al., 2022). As a result, plant invasion is prevalent because of high exploitation pressures experienced by the forest community (Obiri, 1997; Lawes et al., 2004; Gugushe et al., 2009; Furukawa et al., 2011a, b; Lewis et al., 2015; Sosibo et al., 2022). Despite this, they play an important role in regulating the atmosphere through carbon sequestration (Lewis et al., 2015; Jenkins and Schaap, 2018; Bentsi-Enchill et al., 2022), and while only occupying a relatively small area, they are the most biodiversity-rich ecosystem (Brodie et al., 2014; Armenteras et al., 2023). As well as their important biodiversity-richness, they also provide several ecosystem services to humans for subsistence (Armenteras et al., 2023; Ezzine de Blas et al., 2011).

Most indigenous forests are in remote areas, where there are minimal governmental developments for communities (Shackleton et al., 2007; Paumgarten and Shackleton, 2011; Shackleton et al., 2019; Constant and Taylor, 2020). The growing human population increases the rate of exploitation of forest resources in these communities (Lewis et al., 2015; Manqele et al., 2018; Shackleton et al., 2019; Dar et al., 2022). In Colombia, the major turnout of forest degradation results from the excess use of forest products (Armenteras et al., 2023). For the past decade, South Africa has experienced an increase of about 20% in population size (Stats SA, 2022). The increased cost of living, and high unemployment rates in rural communities have been driving the dependency on forest resources (Nomtshongwana, 1999; Robertson and Lawes, 2005; Lawes et al., 2007; Shackleton et al., 2019; Dar et al., 2022).

Forest resources provide several benefits aside from the socio-economic ones, these include medicinal plants, firewood, food, and cultural as well as spiritual beliefs (Shackleton et al., 2007; Codjo et al., 2017; Talukdar et al., 2021; Sosibo et al., 2022). In KwaZulu-Natal, a significant proportion of medicinal plants are sourced from natural forests (Nomtshongwana, 1999; Codjo et al., 2017), with more than 65% of the plants in Durban markets harvested from forests and savannahs (Shackleton et al., 2007). Several studies have investigated the culture and spiritual values of forests (Dold and Cocks, 2002; Fisher, 2004; Banzouzi et al., 2008; Aloke et al., 2022) and in communities near the forests, they harvest pole-sized timber to build houses, kraals, and fencing (Nomtshongwana, 1999; Robertson and Lawes, 2005; Paumgarten and Shackleton, 2009; Leaver and Cherry, 2020a, b).

In addition, communities collect firewood from the forests as a primary source of fuel, while some collect it to sell it and supplement their low incomes or unemployment (Gugushe et al., 2009; Furukawa et al., 2011a, b). With the increasing food costs, forests provide edible vegetation to communities to alleviate poverty and generate income through sales (Fisher, 2004; Furukawa et al., 2011a, b; Codjo et al., 2017; Njwaxu and Shackleton, 2019; Talukdar et al., 2021). By so doing, they keep the costs minimal while investing their income in education and emergency needs (Djagoun et al., 2022), such as deaths and retrenchment (Shackleton et al., 2007). Apart from the socio-economic and materialistic benefits, cultural and spiritual beliefs hold a significant interconnection between people and the forest (Constant and Taylor, 2020; Djagoun et al., 2022). All of this results in high forest resource dependency (Shackleton et al., 2007; Codjo et al., 2017; Nerfa et al., 2020; Armenteras et al., 2023).

With this in mind, excessive use and high reliance on natural resources threaten resource availability (Furukawa et al., 2011a, b; Dar et al., 2022; Armenteras et al., 2023). In addition, the forest's structural composition is altered as a result of severe disturbances (Robertson and Lawes, 2005; Williams et al., 2013; Adie et al., 2013; Leaver and Cherry, 2020b) and the forest community is affected by altered composition, including the fauna that depends on them (Menton, 2003; Lewis et al., 2015; Leaver et al., 2021; Sosibo et al., 2022). While this is mostly relevant to conservation and biodiversity, it also impacts the ecosystem services that benefit local communities.

For forest conservation and management purposes, the perceptions of local communities are crucial and need to be considered (Ite, 1997; Robertson and Lawes, 2005; Armenteras et al., 2023). So, integrating the communities' cultural and spiritual beliefs with conservation management is important (Menton, 2003; Constant and Taylor, 2020). The present study assessed the benefits and costs of anthropogenically disturbed, mistbelt, indigenous forests to the nearby rural communities. We surveyed rural communities near the indigenous forests to document (1) their perceptions, values, and use of the forests, (2) how the disturbance of forests has an impact on them, and lastly (3) to provide conservation implications. We predicted that (1) the importance of forests will be influenced by the duration of time spent in the community and employment status; (2) age and gender will influence the type of resources used from the forest; and (3) the support for protection and conservation will be positively influenced by age and education.

4.3. Methods

4.3.1 Study areas

We conducted the study from December 2023 to January 2024 in southern KwaZulu-Natal, South Africa, mainly in the Harry Gwala District Municipality. The areas studied were Dazini (29°57'58.12" S; 29°39'53.53" E), Mpumlwane (29°58'46.24" S; 29°41'21.11" E), Ndodeni (29°59'17.37" S; 29°40'21.95" E), Mthintwa (30°3'46.49" S; 29°33'0.83" E), Eziqalabeni

(30°3'34.90" S; 29°31'17.29" E), KwaGoso, (30°3'44.30" S; 29°34'37.26" E), and Mfulamhle (30°3'21.03" S; 29°42'15.44" E) (Figure 4.1). Our study areas are characterised by summer rainfall, with mean annual temperatures ranging from +/- 600mm to +/- 1400mm (Harry Gwala District Municipality, 2008). Due to the differences in the altitudes, the temperatures in these regions fluctuate and are characterised by warm, wet summers and cold, dry winters with an average temperature of 16.3°C annually (Elliott and Escott, 2014). The south-facing slope is nested by indigenous forests. The mosaic and climatic conditions (cold and wet) result from different biota, with grassland being dominant (Ubuhlebezwe Municipality, 2011; Umzimkhulu Local Municipality, 2011).

In addition, several wetlands are found in valleys formed by the steep topography with flat valleys. Several river valleys run through the indigenous forests, including the Pholela, Ngwangwane, and Ndawane systems (Elliott and Escott, 2014). The population of this region is estimated to be over 560,000 individuals, dominated by females (53.2%) (Stats SA, 2022). A greater proportion (7.6%) of individuals in this region do not have any level of education, while others (6.7%) have a higher level of education (Stats SA, 2022).

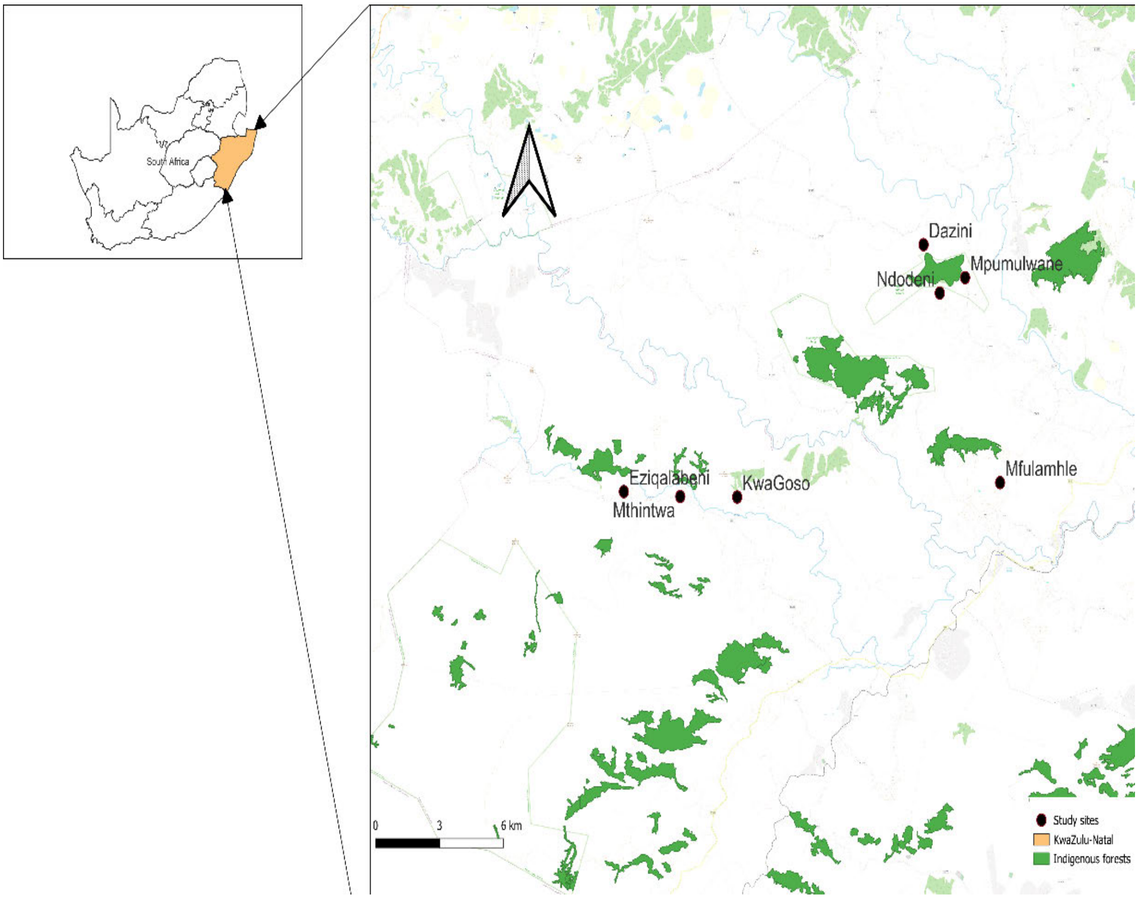

Figure 4.1: Map showing the location of the indigenous forests and the rural communities that participated in the study in southern KwaZulu-Natal, South Africa. (Note: KwaZulu-Natal is shown in orange in the inset).

4.3.2 Data collection

We developed a questionnaire (Supplementary information Table S4.1) and obtained University of KwaZulu-Natal Humanities Ethics permission (HSSREC/00005804/2023) to administer it to people over 18 years of age, after they had completed a consent form. We collected data on perceptions of local community members regarding the use, role, and impact of logging activities on nearby mistbelt forest through a stratified random administration of questionnaires, targeting people living near the five natural forests: namely KwaYili, Goso, MaXhegu, MaShisa, and Hhoha. Permission to conduct the study was obtained from the Local chief. Questionnaires were administered through trained assistants, who recorded all the responses. The questionnaires were conducted in a language preferred by the respondents, alternating between IsiZulu and English.

All responses to open-ended questions were recorded verbatim (exhaustively) to avoid recorder bias. In each homestead, persons over 18 years old took part in the survey. Each respondent was asked questions in the absence of other respondents as a means to avoid duplication of responses and to get responder originality without the influence of other respondents. The questionnaire consisted of three sections; the first section gathered information about demographic variables, such as age, level of education, employment status, and how many years one has lived in a particular area (Supplementary information Table S4.1). In the second section, respondents were asked whether the forest is important to them, what resources they get from the forest, whether there has been a change in the abundance of large trees, how the change came about, whether it was because of the local community members or other people (Supplementary information Table S4.1). In the third section, respondents were asked about common beliefs, protection, and their thoughts on changes in forest structure (Supplementary information Table S4.1).

4.3.3 Data analyses

We used R version 4.4.0 (R Core Team, 2024) to run generalised linear mixed models (GLMMs) to test the effects of our fixed effect against our response variables (Table 4.1). Upon running the analysis, we used the lme4 package to fit our models (Bates et al., 2015). Our response variables were the (a) importance of the forest, (b) contribution to well-being, (c) what if the forest disappears, and (d) support of forest protection. These were each run against different models (Table 4.1) created using the fixed effects (1) age, (2) gender, (3) education,

(4) employment, and (5) duration of time in the area (hereafter as duration). In all of our models, villages were included as a random effect.

Table 4.1: The fitted models with a combination of fixed effects ran against each of the four response variables. The first model is the full model containing all fixed effects, and the rest are a combination of different fixed effects that were different from the full model. In these models, villages were used as a random effect throughout.

Model No	Fixed effects
1	Age + Gender + Education + Employment + Duration
2	Age
3	Duration
4	Age + Education
5	Age + Gender
6	Education + Duration
7	Education + Gender + Duration
8	Age + Gender + Employment
9	Gender + Education
10	Age + Employment
11	Age + Education + Employment
12	Gender + Education + Employment + Duration
13	Age + Duration
14	Age + Gender + Education + Duration

The visualised inspection of residual plots did not show any deviations from normality. Therefore, we used the AICcmodavg package (Mazerolle, 2016) to score our models and select the best model(s) for each response variable using ΔAICc. The models with the $\Delta AICc \leq 2$ were considered the best (Burnham and Anderson, 2002). We averaged the models to get the best estimating model for each of our four response variables. The averaged models were ranked according to their best model for each response variable (Table 4.4). We then performed a multi-model inference using the package MuMIn (Bartoń, 2024) to average all the models that had the $\Delta AICc \leq 2$ for each of our response variables. Finally, we checked for multicollinearity in our fixed effects and did not find any correlation. This was performed using the Variance

Inflation Factor (VIF). The VIF value closer to one was regarded as having no correlation, and all of our fixed effects had a VIF value closer to one (Supplementary Information Table S4.2). We also used IBM SPSS V29 to run the chi-square analyses to compare differences between our fixed effects.

4.4 Results

We conducted a total of 360 questionnaires across seven villages and rural communities. The number of questionnaires conducted in each community varied according to the village size. We conducted the questionnaires in Mthintwa (n = 54), Eziqalabeni (n = 41), KwaGoso (n = 19), Mfulamhle (n = 62), Ndodeni (n = 70), Mpumulwane (n = 54), and Dazini (n = 60). There was a significant difference in the proportion of males and females in our respondents ($\chi^2 = 40$, d.f. = 1, $P < 0.001$). Most of our respondents (67%) were females (Table 4.2). The age of our respondents ranged from 18 to 50+ years, with a notable significant difference in the proportion across age groups ($\chi^2 = 33$, d.f. = 4, $P < 0.001$). The age group 50+ had more respondents (29%) than the rest of the group (Table 4.2). The level of education varied ($\chi^2 = 270$, d.f. = 3, $P < 0.001$), and most of our respondents (55%) were educated to the secondary level (Table 4.2). A significant number of our respondents (88%) were unemployed ($\chi^2 = 206$, d.f. = 1, $P < 0.001$), and most (74%) had stayed a duration ($\chi^2 = 673$, d.f. = 4, $P < 0.001$) of at least 20 years in their village (Table 4.2).

We obtained models that best explained the variance of our response variables that were run against the fixed effects (Table 4.3). Only one response variable (importance of forest) had one fixed effect in the best approximating model (Table 4.3). The rest of the response variables had multiple fixed effects in the best approximating model (Table 4.3). Two of the remaining three response variables had three fixed effects, while one had two in the best approximating model. The best approximating model for the “Importance of forest” variable had only one fixed effect (duration). Meanwhile, "Contribution to wellbeing" contained three fixed effects (education, gender, duration) in the best approximating model. The question "What if the forest disappears" had two fixed effects (age and gender), similar to the statement "support forest protection" (age and education). For the response variables "importance of forest" and "contribution to well-being", the important fixed effect was the duration. Similarly, "support forest protection" and "What if forest disappears" had age as their important fixed effects. Although we present only the best models, there were other models relevant to explain our response variables (models containing the $\Delta AIC_c < 2$). In addition, "Duration" was the best estimating model for two of our response variables ("Importance of forest" and "Contribution to well-being"). This was also the case for age, as it was the best model for two response variables ("What if the forest disappears" and "Supports forest protection").

Table 4.2: The demographic representation of respondents and the proportion of responses to each demography.

Demographics	Respondents (n)	Proportion (%)
Village name		
Mthintwa	54	15
Eziqalabeni	41	11
KwaGoso	19	5
Mfulamhle	62	17
Ndodeni	70	19
Mpumulwane	54	15
Dazini	60	17
Gender		
Male	120	33
Female	240	67
Age group		
18-25	40	11
26-33	86	24
34-41	73	20
42-49	58	16
50+	103	29
Education		
Primary	132	37
Secondary	197	55
Tertiary	13	4
None	18	5
Employment status		
Employed	44	12
Unemployed	316	88
Duration of time in area		
0-5	14	4
6-10y	15	4
11-15y	23	6
16-20	40	11
20+	268	74

Table 4.3: The rank of models ran against the four response variables according to their best approximating model. The number of parameters is represented by "K". The models are ranked based on the corrected Akaike Information Criterion (AIC_c). Models with AIC_c weight ($\boldsymbol{w_i}$) greater than zero are presented. Models with the ΔAICc< 2 are considered the best in estimating the variance of our response variables.

Response variables	**Models**	**Fixed effects**	**K**	**AIC_c**	***w_i***	**ΔAIC_c**
Importance of forests	3	Duration	4	87.34	0.31	0.00
	6	Education + Duration	5	88.00	0.22	0.66
	7	Education + Gender + Duration	6	88.78	0.15	1.44
	13	Age + Duration	5	89.29	0.12	1.95
	12	Gender + Education + Employment + Duration	7	90.53	0.06	3.18
	14	Age + Gender + Education + Duration	7	90.77	0.06	3.42
	1	Age + Gender + Education + Employment + Duration	8	92.51	0.02	5.17
	9	Gender + Education	5	92.72	0.02	5.38
	5	Age + Gender	5	93.87	0.01	6.53
	2	Age	4	94.41	0.01	7.07
	4	Age + Education	5	94.78	0.01	7.44
	8	Age + Gender + Employment	6	95.58	0.01	8.23
Contribution to wellbeing	7	Education + Gender + Duration	6	426.65	0.26	0.00
	12	Gender + Education + Employment + Duration	7	427.22	0.19	0.57
	6	Education + Duration	5	427.59	0.16	0.94
	14	Age + Gender + Education + Duration	7	428.06	0.13	1.41
	3	Duration	4	428.26	0.11	1.61
	1	Age + Gender + Education + Employment + Duration	8	428.70	0.09	2.05
	13	Age + Duration	5	429.89	0.05	3.24
What if forest disappears	5	Age + Gender	5	494.42	0.22	0.00
	2	Age	4	495.65	0.12	1.23
	13	Age + Duration	5	495.76	0.11	1.35
	3	Duration	4	495.86	0.11	1.44

	8	Age + Gender + Employment	6	496.01	0.10	1.59
	6	Education + Duration	5	497.00	0.06	2.59
	10	Age + Employment	5	497.05	0.06	2.64
	14	Age + Gender + Education + Employment	7	497.24	0.05	2.83
	4	Age + Education	5	497.30	0.05	2.89
	7	Education + Gender + Duration	6	497.95	0.04	3.53
	9	Gender + Education	5	498.71	0.03	4.29
	11	Age + Education + Employment	6	498.74	0.03	4.32
	1	Age + Gender + Education + Employment + Duration	8	498.87	0.02	4.46
	12	Gender + Education + Employment + Duration	7	499.51	0.02	5.09
Support forest protection	4	Age + Education	5	443.74	0.22	0.00
	2	Age	4	444.33	0.16	0.59
	11	Age + Education + Employment	6	444.95	0.12	1.21
	10	Age + Employment	5	445.49	0.09	1.75
	9	Gender + Education	5	445.92	0.07	2.18
	6	Education + Duration	5	446.19	0.06	2.45
	13	Age + Duration	5	446.37	0.06	2.63
	5	Age + Gender	5	446.37	0.06	2.63
	8	Age + Gender + Employment	6	447.53	0.03	3.79
	7	Education + Gender + Duration	6	447.81	0.03	4.07
	14	Age + Gender + Education + Duration	7	447.83	0.03	4.09
	3	Duration	4	448.32	0.02	4.58
	12	Gender + Education + Employment + Duration	7	448.92	0.02	5.18

Table 4.4: The estimated size coefficients of the averaged fixed effects in the best models.

Response variable	Fixed effects	Estimate size
Importance of forest	Duration	-0.036
	Education	0.011
	Gender	0.006
	Age	0.001
Contribution to wellbeing	Duration	-0.080
	Education	0.043
	Gender	0.058
	Employment	0.019
	Age	-0.002
What if forest disappears	Age	0.032
	Gender	-0.048
	Duration	0.014
	Employment	-0.008
Support forest protection	Age	-0.030
	Education	0.030
	Employment	0.024

4.4.1 The importance and use of forest in the nearby community

A significant proportion of community members (n = 330, 92%) residing near the forests appreciate the availability of the forest and consider the forest to be important ($\chi^2 = 250$, d.f. = 1, $P < 0.001$). The best fixed effect to approximate the variance for the importance of the forest was the time spent in the community (Duration). Many of these respondents (n = 249, 69%) had spent at least 20 years living in their neighbourhood, which was made up of a greater proportion of females (n = 175, 65%) than males (n = 93, 35%). In total, there was a significant gender difference ($\chi^2 = 32$, d.f. = 1, $P < 0.001$), and females accounted for 60% (n = 216) of the respondents who said that forests are important to their families and neighbourhoods. The importance of the forest was driven by a variety of forest resources such as plants (for food), trees, firewood, etc. (Table 4.5). These combined resources (plants, trees, and firewood) accounted for the highest proportion (30%), while other important aspects of the forest included water (18%), shade and grazing (27%), culture and medicine (18%). A small proportion (8%) advocated against the importance of forests (Table 4.5).

Table 4.5: A summary of respondents in terms of the importance of forests when they were asked how forests are important to them and their families.

Forest importance	Respondents (%)
Plants, trees, firewood	30
Water	18
Shade and grazing	27
Culture and medicine	18
Not important	7

In addition to forest importance, a significant proportion of respondents (89%) said that the forest benefited their well-being ($\chi^2 = 206$, d.f. = 1, $P < 0.001$). We found that the time spent in the community also explained the variability in the contribution to well-being. As a result, we had more elders (20+ years) in our response variable (contribution to well-being). A greater proportion (67%) of these respondents admitted that the forest contributed to their well-being (n =241). The majority of these respondents (57%) were females, with primary (34%) and secondary (48%) levels of education, with tertiary education only accounting for a small number (7%). A small portion of them (13%) did not see any contribution by the forest to their well-being.

4.4.2 Perceptions, values, and beliefs of the forests by the nearby communities

When asked about their thoughts on forests, our respondents provided a variety of responses, which they shared within each community (Figure 4.2). While firewood and other resources (plants, water, medicine, timber) were common in their responses, some of the community members feared the forest because of the beliefs they shared about the forest (Figure 4.2). About (15%) of the communities believed that the forest had some form of witchcraft associated with it. More than 20% of the respondents did not participate regarding their instant thoughts of the forest (Figure 4.2). It was interesting to show differences within and across communities regarding what came to mind when they thought about the forest (Figure 4.2).

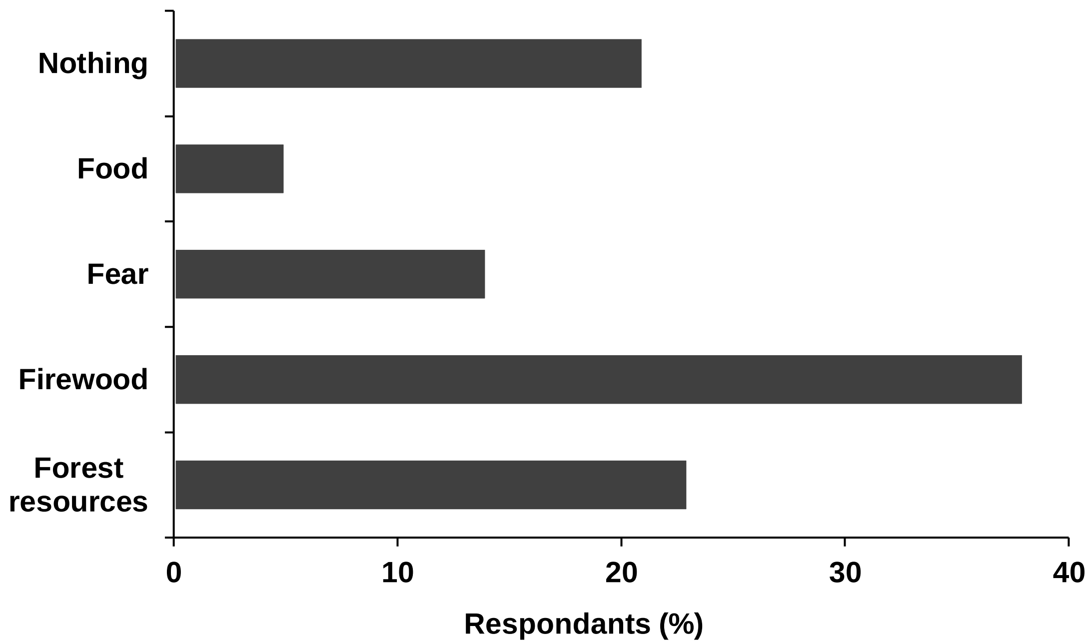

Figure 4.2: The response proportion from respondents to "What comes to your mind when you think about the forest?"

The values of the forest were measured by how they would cope without the forest and if they supported the idea that the forest should be protected. Most of our respondents (76%) said they would struggle to cope with the depletion of forest resources. Meanwhile, a proportion of respondents (22%) thought they would cope without the natural resources. Despite this, across communities, a small proportion of respondents (13%) did not support the protection of the forest.

However, a significant number of respondents (89%) supported the protection of the forest ($\chi^2 = 197$, d.f. = 1, $P < 0.001$). As age was the best estimating fixed effect (see Table 4.4), the majority of our responses (25%) came from older individuals (50 years and above). In addition, there was a low employment rate (11%) among our respondents who supported forest protection (Table 4.3).

4.4.3 Impact of forest disturbance on nearby communities

The disturbance gradients influenced how community members perceived the forest (Figure 4.3). We assessed how the disturbance affects the perceptions of nearby communities by comparing the response given by the communities near logged and relatively intact forests. Respondents appreciate the forest more than that of a relatively intact forest. About 64% of the respondents from logged forests said that the forest is important to them and their families and contributes to their well-being as shown in Figure 4.3. Meanwhile, the responses from the communities near the relatively intact forests to forest importance and contribution to well-being were 27% and 24%, respectively (Figure 4.3). Although there are differences in the proportion of group responses, there were no significant differences between the groups ($P = 0.91$, Figure 4.3).

Moreover, respondents from logged forests support the protection of the forest more (62%) than those from nearby intact forests (25%), as shown in Figure 4.3. Overall, 73% of the respondents thought they would face many struggles without the forests. Among these respondents, 69% came from communities near disturbed forests.

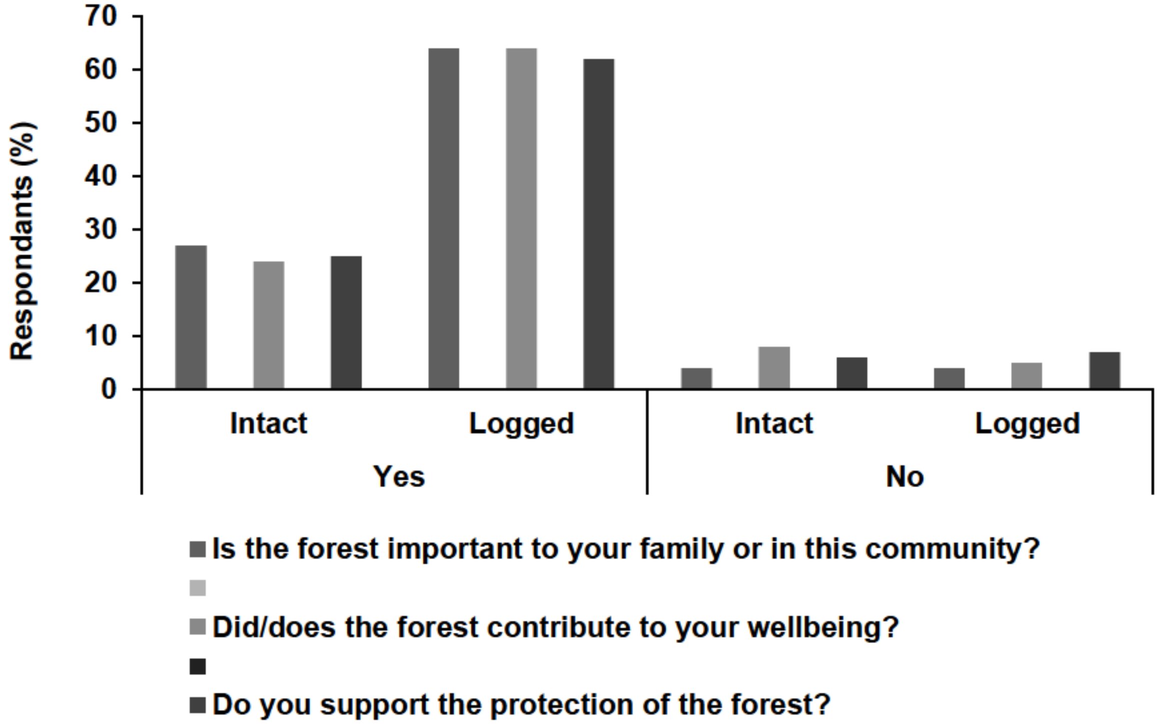

Figure 4.3: The responses given by communities near the logged and unlogged (intact) forests to the importance of forests, the contribution of forests to well-being, and support in favour of forest protection.

4.5 Discussion

The perceptions of forests depend on the benefits accumulated by the local users from the forest (Figure 4.3). Generally, community members residing near forests have a positive relationship with the forest because of subsistence benefits (Shackleton, 1996; Menton, 2003; Fisher, 2004; Gugushe et al., 2008). As such, people who benefit more from the forest perceive the forest as the most crucial aspect of their lives. Therefore, it is likely that the relationship between people and their nearby forest is based on forest resources such as firewood (Robertson and Lawes, 2005; Shackleton and Shackleton, 2006; Nerfa et al., 2020). In the present study, people appreciated the forest and considered it valuable because of the resources and services they obtained from the forests for subsistence purposes (Figure 4.2; Table 4.5). The latter has been well-documented across several countries globally (Shackleton, 1996; Menton, 2003; Fisher, 2004; Gugushe et al., 2008; Codjo et al., 2017; Constant and Taylor, 2020; Leaver and Cherry, 2020a, b; Dar et al., 2022; Armenteras et al., 2023). As predicted, the driver of the importance of this "treasure" is the time spent in the community. The more time spent in the community meant that they had been relying on the forest for a longer time and appreciated its resources and ecosystem services. Similarly, Ofoegbu et al. (2017) reported that dependency on the forest is a result of the duration of time spent in the community. As such, age is also incorporated into the time spent in the community. Older community members in this study relied more on the forest than younger individuals. Older individuals (50+) accounted for 27% of the individuals agreeing with the importance of the forest across all communities. This is because they no longer rely on jobs to support their families because of their age (Ofoegbu et al., 2017).

There were differences in terms of how the local communities used forest products. Age, gender, and household requirements were the key determinants of forest product use. The high proportion of firewood resulted from the high participation of females in this study. Generally, females collect firewood, while males mostly collect pole-sized trees and plants, as found in the Eastern Cape Province, South Africa (Gugushe et al., 2008). We report on the dominance of forest use for firewood, as in other studies; for example, Gugushe et al. (2008) found more than 80% of villagers use the forest to collect firewood. Other important forest resources included medicine and cultural factors, as in Malawi and Benin (Codjo et al., 2017; Nerfa et al., 2020).

The high unemployment rate in our study area (89%) was the primary cause of the socio-economic difficulties people experienced. This creates more dependency on forests to alleviate economic struggles (Shackleton et al., 2019; Dar et al., 2022). Similar to our study, Cameroon and

Kenya reported more dependency on forest products by the less fortunate local members of communities (Fisher, 2004; Chia et al., 2013). Less fortunate people are more likely to depend on the forest to supplement their low-income rate, which drives the dependency on forest products (Opperman et al., 2018). Meanwhile, fewer respondents (8%) did not consider the forest important for their livelihoods, which was influenced by their high-income rate and employment levels, as found in other studies elsewhere (Gugushe et al., 2008; Chia et al., 2013). Therefore, forests are crucial in supplementing the local communities to overcome socio-economic difficulties.

While not exclusive to socio-economic benefits, forests contribute to people's well-being (Sosibo et al., 2022). Consequently, they are also valuable and crucial to local communities for non-economic benefits (Shackleton et al., 2007; Constant and Taylor, 2020). In the present study, forests were valued for medicinal plants. Medicinal plants were personally used to cure diseases because of limited access to both public and private healthcare facilities. Apart from personal use, participants could generate revenue from the *muthi* products obtained from the forest and sold. We encountered several traditional healers who used the forest as a source of medicinal plants. Some were based in urban areas and would travel to rural communities to get medicinal plants in the forest to sell in the urban areas. These results were similar to findings in other parts of Africa (Dold and Cocks, 2002; Codjo et al., 2017; Opperman et al., 2018; Talukdar et al., 2021).

In addition, the forests served as a source of water in these communities. The poor supply of government services, such as water and sanitation, is supplemented by forest resources. The houses they lived in were mostly built using pole-sized young trees. As such, the most commonly used tree species is *Ptaeroxylon obliquum* (commonly known as *umthathi*). The excess use of this species is because of the variety of its uses. It is used to build kraals, fence properties, and build houses because of its strength and reliability. The use of forest resources for building materials is well-known (Nomtshongwana, 1999; Lawes et al., 2007; Shackleton et al., 2007; Codjo et al., 2017; Nerfa et al., 2020; Leaver and Cherry, 2020a, b; Talukdar et al., 2021; Dar et al., 2022; Sosibo et al., 2022).

While community members suffered from the unavailability of jobs and low income in their households, forests provided consumable vegetables for food. The most common in these communities are *imfino* (traditional spinach) and *imbati,* which is used for cooking the traditional food *isigwamba*. In addition, because of the affordability crises, they cannot afford to buy supplements for their livestock. Their livestock can graze in the forest, especially those forests that have been disturbed. Alternatively, they collect the feed for their livestock in the kraal. This was the case in the communities near the intact forests. Therefore, forests play a role in alleviating food shortages, especially during the dry season when limited food resources are available. Concerning their culture, forests play a major role in the practice of their cultural beliefs and religion. When a person passes away, they communicate with the deceased using buffalo thorn (*Ziziphus mucronata),* a tree species (commonly known as *umlahlankosi*), which they get from the forest (see Cocks and Moller, 2002; Codjo et al., 2017; Opperman et al., 2018).

The importance of community perceptions is acknowledged globally in countries such as Brazil and Colombia (Menton, 2003; Armenteras et al., 2023). This is because of the connection and the relationship communities have with the forest (Djagoun et al., 2022). However, the forest is only important if the local people benefit from it (Robertson and Lawes, 2005). In West Africa, people appreciate the forest because of its services and resources (Codjo et al., 2017; Djagoun et al., 2022). The disturbances in the forest influence how people perceive the forest in terms of importance and value. As in West Africa, the present study showed that the significance and the value of the forest were driven by the actual use of resources by local communities (Figure 4.3).

As a result, communities care more about access to forest resources than forest conservation (Robertson and Lawes, 2005). However, based on our results, some community members considered the protection of the forest, especially in areas where the forest is heavily disturbed. Most of our respondents (62%) supported forest protection. This was driven by their perceived suffering following natural resource depletion. In southern KwaZulu-Natal, more than 80% of people using the forest approved of implementing authorised access into the forest (Robertson and Lawes, 2005). The authorised access to forests is also documented in countries such as Cameroon and parts of Europe (Guertin, 2003; Tsanga et al., 2014). In the present study, 72% of our respondents suggested that the chief ruling the community should be responsible for the protection of the forest. Meanwhile, 11% of our respondents said that Ezemvelo KZN Wildlife (EKZNW), the provincial authority responsible for maintaining wildlife and biodiversity conservation, should intervene in the protection of forests. However, they were sceptical because they felt that should EKZNW intervene, they might be denied access to the forest completely. Hence, there was a lower proportion leaning toward this solution. This further illustrated a high dependence on the forest and its resources. Similarly, in Brazil, Menton (2003) reported that the disturbance of forests has a remarkable effect on their lives. This is mainly because they use non-timber forest products (NTFPs), and forest disturbance may reduce resource availability (Menton, 2003; Leaver and Cherry, 2020a).

4.6 Conclusions

Forests play a crucial role in the lives of nearby communities by providing resources such as medicinal plants, firewood, and building materials (Codjo et al., 2017; Talukdar et al., 2021; Dar et al., 2022; present study). The high unemployment rate, poor governmental services, and low-income rates magnify the communities' dependence on forest resources for their subsistence. As living costs rise, the demand for natural resources is likely to increase in the future. Forest use is highly dependent on age, gender, and household requirements. As such, elders are most likely to depend on the forest because they are no longer working and unable to provide for themselves. In addition, females collect firewood more, while males collect pole-sized trees as building materials. These natural resources are not only limited to material use, but they also play a major role in the culture and religion of the local community members. This highlights the importance of forests for non-economic benefits. While community members benefit from the forest, they fear the depletion of forest resources, which is substantiated by the support for forest protection. The latter is driven by access to forest resources rather than conservation and management. Hence, they are reluctant to external organisations' intervention. We highlight the need to balance resource provision with conservation efforts. Therefore, it is essential to integrate local cultural needs and spiritual beliefs into conservation strategies, ensuring a balance between ecosystem health and community well-being. Educating about the importance of forests in biodiversity and the environment is also crucial for management and conservation purposes.

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4.9 Supplementary Information

Supplementary information Table S4.1. The consent form and questionnaire used in the present study.

CONSENT TO PARTICIPATE IN THE STUDY
Participation in this study is anonymous, and therefore, no identity shall be revealed.
I have been informed about the study entitled "The perceptions of the impacts of natural forest quality on the surrounding communities." I understand the purpose and procedures of the study. I have been given an opportunity to answer questions about the study that have been asked to my satisfaction. I declare that my participation in this study is entirely voluntary and that I may withdraw at any time. If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at +27 72 154 0685.
If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact Prof Downs and/or Dr Maseko of the University of KwaZulu-Natal.

1. PERSONAL DETAILS

(a) Gender

Male		Female	

(b) Age group

18-25 years		26-33 years		34-41 years		42-49 years		50+ years	

(c) Level of education

Primary		Secondary		Tertiary		None	

(d) Employment

Employed		Unemployed	

(e) Village name

(f) How long have you lived in the community?

0-5 years		6-10 years		11-15 years		16-20 years		20+ years	

(f) Briefly, what aspect do you value the most about living in this area? Why?

2. FOREST

(a) Is the forest important in your family or in this community?

Yes		No		Not sure	

(b) How is the forest important to you?

Water source	Culture	Shade	Plants	Trees	Firewood	Cattle/goat grazing		Other

How is the above-mentioned important?

(c) What do you normally use forest for?

Water source	Culture	Shade	Plants	Trees	Firewood	Cattle/goat grazing		Other

How you use the forest for the above-mentioned?

(d) Have you noticed any changes in the forest quality in terms of the number of big trees?

Yes		No		Not sure	

If yes, what do you think was the cause?

Can you elaborate more when and how this happened?

Was it local or other people that caused this?

Yes		No		Not sure	

If yes, Explain

(e) Did/does the forest contribute(d) to your wellbeing?

Yes		No		Not sure	

If yes, please specify.

(f) Have you noticed any changes in the forest quality in terms of the number of animals?

Yes		No		Not sure	

If yes, what do you think is the cause?

(g) Briefly, what would you say is/are the cost(s) of change in the forest structure?

(h) Briefly, what would you say is/are the cost(s) of change in the forest animals?

(i) Which wild animals do you see in your forest more frequently?

Fish	Snakes	Birds	Mammals	Other

If other, please specify.

(j) Have you noticed any change in the forest in terms of birds and mammal species

Yes		No		Not sure	

If yes, why?

3. PERCEPTIONS ABOUT THE FOREST

(a) What local name(s) do you use when referring to the local forest near your community/homestead?
(b) What is the meaning of this/these words?
(c) Are there any beliefs about the forest that are shared in this community?

Yes		No		Not sure	

If yes, specify.
(d) What comes to your mind when you think about the forest?
(e) What do you think would happen if the forest disappears?
(f) Are you in support of the forest protection?

Yes		No		Not sure	

Why?
(g) If yes, why do you think the forest should be protected?
(h) If yes to the above, who do you think should be responsible to ensure that the forest is effectively protected? Why?
(i) Does the forest have security guards

Yes		No		Not sure	

(j) What do you think can be done to protect the forest in the short term or long term?
Do you have any further questions or things you would like to say?
Many thanks. We will share feedback with the community once we are finished our study.

Supplementary Table S4.2. The Variance Inflation Factor (VIF) values for our fixed effects. The VIF value closer to one means no significance and therefore, no correlation. When 1 < VIF < 5, this is considered moderate and the estimates can be reliable. When VIF > 5, this means that there is high collinearity and the coefficient estimates may be unreliable.

Fixed effect	**Variance Inflation Factor (VIF)**
Age	1.26
Gender	1.11
Education	1.07
Employment	1.01
Duration	1.13

CHAPTER 5

General discussion, conclusions and recommendations

5.1 Introduction

Anthropogenic disturbance persistence is causing a major threat to forest ecosystems on a global scale (Lawes et al., 2007; Tegegne et al., 2016; Senior et al., 2018; Armenteras et al., 2023). Land use change, fragmentation, and conversion to agriculture and exotic plantations are the major results of forest degradation and destruction (Fahrig, 2003; Ahrends et al., 2010; Esaete et al., 2023). In addition, the rapid increase in human population accelerates the rate at which forests are disturbed (Lewis et al., 2015; Shackleton et al., 2019). The intensity and period of disturbance vary along with their impact on biodiversity. For example, in South Africa, the majority of indigenous forests are nested near local communities (Shackleton et al., 2007; Leaver and Cherry, 2020). The rate of forest use and exploitation determines the impact on forest flora and fauna. As such, understanding the impact of disturbances in forest ecosystems is important to inform conservation and management majors of biodiversity (Bitani et al., 2024). In this study, we aimed to investigate to effect of forest disturbances on biodiversity and nearby communities. Consequently, we assessed (1) the effect of forest anthropogenic disturbances in Africa, (2) the response of birds' taxonomic and functional diversity to local and landscape characteristics, and (3) the perceptions of the importance, values, and role of forests by their nearby communities.

5.2 The effect of anthropogenic activities on African forests

African forests are constantly being threatened by anthropogenic activities. Understanding the dynamics of disturbances and their impact on forest ecosystems is crucial. However, there is a gap in the development of initiatives for effective management and conservation (Armenteras et al., 2006; Leaver and Cherry, 2020). Consequently, we assessed how the disturbances affect forests in Africa, incorporating the use of forest birds as the indicators of anthropogenic effects, as well as conservation implications (Chapter 2). The results showed that logging, fragmentation, and harvesting are the most common results of anthropogenic activity across Africa. The forest structure and composition are negatively impacted by anthropogenic activities, resulting in low resource availability and local extinction of biodiversity (Chapter 2). In the process, the structural complexity and heterogeneity are compromised. As severe as these disturbances are, there has been a bias in research efforts and countries in terms of assessing forest disturbances. In terms of forest fauna, more research was focused on avifauna as the indicator of forest disturbances. Avian communities have a large distribution range and have allowed the researcher to explore their ecological role and selection of forest patches as a response to ecosystem health and quality. Therefore, it is important to incorporate forest fauna when assessing the disturbance as they infer anthropogenic effects (Chapter 2).

5.3 Effect of local and landscape characteristics on functional diversity

The selection of forest patches by the avian community is driven by the type of disturbances and their intensity (Devictor et al., 2008). The local and landscape characteristics drive the diversity of birds across patches (Bitani et al., 2024). Understanding how birds are affected by these characteristics is essential for biodiversity management and conservation. We assessed the impact of structural complexity, heterogeneity, and categorical disturbance on birds' taxonomic and functional diversity (Chapter 3). The overall results indicated the positive influence of structural complexity and heterogeneity on bird species richness and abundance. The functional richness and evenness increased with lowered patch disturbance highlighting the sensitivity to disturbance. The categorical disturbance had a negative influence on both the taxonomic and functional diversity (Chapter 3). In terms of habitat-specificity, more specialist bird species were occupying the primary forest patch (relatively intact) including the endangered southern ground hornbill (*Bucorvus leadbeateri*) and the Cape parrot (*Poicephalus robustus*). However, disturbed patches also contained the forest specialists to a lesser extent, including the Cape parrot (Chapter 3).

5.4 Perceptions of the importance of forests by the nearby communities

As most of the forests in South Africa are located in remote areas near local communities, exploring the knowledge of community members is important to understand the roots of disturbances taking place in indigenous forests (Shackleton et al., 2007; Lewis et al., 2015). We assessed the perceptions, values, importance, and role of Southern Mistbelt Forests held by nearby communities (Chapter 4). The results indicated the importance of forests in alleviating poverty and financial struggle in the local communities. The forests are harvested for medicinal plants, fuelwood, materials for infrastructure, etc. Local communities value the forest further because of its non-materialistic benefits, including their spiritual and cultural belief benefits (Chapter 4). This highlighted the benefits of part from the materials they obtain from the forest.

5.5 Final conclusions and recommendations

Forest disturbances are a threat to forest ecosystems and biodiversity that depend on the ecosystem. Anthropogenic activities such as logging, fragmentation, harvesting, etc., are largely contributing to forest loss and degradation. In research assessing these disturbances, other taxa need to be incorporated, in addition to avifaunal, to understand the magnitude and future direction of these disturbances. Local and landscape characteristics are the main drivers of avifaunal distribution which allows for the assessment of ecosystem health by providing early predictions of disturbances. In the Southern Mistbelt Forest in KwaZulu-Natal, bird functional diversity is largely influenced by structural complexity, heterogeneity, and categorical disturbances. Patch selection by bird species is driven by the high structural complexity and heterogeneity at low disturbance. Therefore, understanding the distribution of avian communities can inform us of the present state of the forest ecosystem. In addition, we highly recommend the assessment of multiple response variables (taxonomic and functional diversity) to enhance the quality of results in avian studies. Moreover, we recommend including other microhabitats (leaf litter, bare ground, tree richness, etc.) and landscape covariates (patch size, connectivity, adjacent matrix, etc.) when assessing birds' functional response to validate the outcomes and research. Local communities can provide valuable information on the disturbance of forests as they constantly use the forest. Therefore, it is recommended that we include the perceptions of local communities in research. This will serve as a means to integrate conservation measures with their beliefs to enhance forest management and implications.

5.6 References

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