Floristic Composition and Vegetation Structure of Ugalla River National Park, Western Tanzania: An Assessment of Early Post-Gazettement Ecological Recovery

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Author's Contributions

IOI (corresponding author) conceived and designed the study, developed the data collection protocols, collected the data, and drafted the manuscript under the supervision of CW and SET. CW conducted the data analysis and contributed to the interpretation of the results. SET critically reviewed and edited the manuscript. All authors read and approved the final version of the manuscript.

Abstract

Protected areas are increasingly established to restore degraded ecosystems, yet evidence of vegetation recovery during the early post-gazettement period remains limited, particularly in African miombo woodlands. This study assessed the floristic composition and vegetation structure of Ugalla River National Park (URNP), western Tanzania, five years after its establishment through the amalgamation of the former North Ugalla Forest Reserve (NUFR) and the former Ugalla River Game Reserve (URGR). Vegetation data were collected from 60 Modified Whittaker plots established along six 30-km transects distributed across the two former management units. Woody plant diversity, species richness, evenness, relative abundance, regeneration status, and diameter at breast height (DBH) distributions were quantified and compared between the former URGR and NUFR.

The former NUFR supported greater woody species diversity, richness, and evenness than the former URGR, indicating a more diverse and compositionally balanced plant community. Species dominance differed markedly between the two, with *Brachystegia spiciformis* dominating the former NUFR and *Terminalia sericea* dominating the former URGR. Most woody species exhibited fair regeneration, although the former NUFR contained more species across all regeneration categories than the former URGR. Diameter-class distributions in both areas displayed an inverse J-shaped pattern, indicating continuous recruitment and ongoing natural regeneration.

These findings demonstrate early vegetation recovery in URNP following gazettement, while differences in floristic composition and vegetation structure continue to reflect historical management regimes and inherent habitat characteristics. The study provides baseline ecological information for monitoring long-term vegetation recovery and supports adaptive management of recovering miombo woodland ecosystems in Tanzania.

Keywords: ecological recovery; floristic composition; regeneration; vegetation structure; post-gazettement.

1.0. | Introduction

Protected areas remain the cornerstone of global biodiversity conservation. They safeguard ecological processes, species diversity, and ecosystem services in landscapes increasingly affected by human activities (Li et al., 2024; Wang et al., 2024). Across sub-Saharan Africa, governments have increasingly upgraded multi-use reserves to strictly protected national parks to halt habitat degradation, restore ecological integrity, and reverse wildlife declines. Similar initiatives have been implemented in Ethiopia and other East African countries to enhance biodiversity conservation and sustainable natural resource management (Siraj et al., 2017). Despite the growing adoption of this conservation approach, the ecological outcomes of upgrading protected areas, particularly during the critical early post-gazettement phase, remain insufficiently documented (Geldmann et al., 2019). The effectiveness of these interventions ultimately depends not only on legal protection but also on the capacity of ecosystems to recover following the removal of chronic anthropogenic disturbances (Pulido-Chadid et al., 2023).

Ecological recovery can occur through either active or passive restoration. Passive restoration, which relies on natural regeneration following the cessation of disturbance, is increasingly recognized as a cost-effective and ecologically viable strategy for restoring large landscapes where intensive management interventions are impractical (Chazdon & Guariguata, 2016; Crouzeilles et al., 2017). In woodland ecosystems, recovery is commonly assessed through changes in floristic composition and vegetation structure. Floristic composition encompasses the identity, richness, diversity, and relative abundance of plant species within a community, reflecting how species are represented taxonomically and quantitatively. Vegetation structure, in contrast, describes the physical organization of plant communities, including tree density, size-class distribution, canopy cover, basal area, and vertical stratification (Kent, 2012; Mligo, 2018). Together, these complementary attributes provide key indicators of ecosystem condition, successional dynamics, habitat quality, and ecological resilience, thereby offering a robust basis for evaluating restoration outcomes and long-term ecosystem recovery.

The importance of understanding floristic composition and vegetation structure extends beyond vegetation ecology, as these factors strongly influence wildlife distribution and habitat suitability. Floristic composition determines the availability of forage resources, while vegetation structure regulates microclimatic conditions, shelter, opportunities for predator avoidance, and access to food and water resources (Ruiz-Jaen & Aide, 2005). Consequently, changes in plant communities during ecological recovery can directly affect the spatial distribution and habitat use of large mammals. Assessing vegetation composition and structure is therefore essential for understanding ecosystem recovery processes and for guiding evidence-based conservation management (Siraj et al., 2017).

In 2019, the Government of Tanzania established Ugalla River National Park (URNP) by amalgamating the former Ugalla River Game Reserve (URGR) and North Ugalla Forest Reserve (NUFR) into a single protected area covering approximately 3,865 km² (URT, 2019; Fig 1). Prior to gazettement, the landscape experienced prolonged anthropogenic pressures,

including settlement expansion, cultivation, livestock grazing, selective logging, commercial beekeeping, and poaching (Hausser et al., 2009; Ismail, 2025). These activities altered vegetation composition, simplified habitat structure, degraded riverine ecosystems, and contributed to substantial declines in large-mammal populations (IIDA et al., 2012; TAWIRI, 2015). The establishment of the national park created an opportunity for passive ecological restoration through reduced human disturbance and the natural regeneration of vegetation communities.

Despite increasing efforts to strengthen protected area networks in East Africa, significant knowledge gaps remain regarding vegetation recovery following park gazettement. In the Ugalla region, historical botanical records have been sparse and have primarily taken the form of preliminary checklists aimed at understanding the habitat requirements of specific flagship species, such as chimpanzees (*Pan troglodytes*) (Moore, 1994). However, these early assessments were limited in spatial scale and lacked the structural detail necessary to track long-term successional trajectories. Consequently, little is known about how plant communities in recovering miombo ecosystems re-establish species composition and structural complexity after the cessation of chronic human disturbances, or how these changes influence broader large-mammal habitat use during the early stages of restoration. Information on species composition, vegetation structure, and distribution patterns along environmental gradients is fundamental for assessing ecosystem recovery trajectories and developing adaptive management strategies for newly established protected areas (Siraj et al., 2017).

This study assessed the floristic composition and vegetation structure in URNP during the early post-gazettement period and examined their ecological implications for the availability of large-mammal habitat. Specifically, the study aimed to: (i) document the floristic composition of URNP, particularly plant species richness, diversity, evenness, and abundance, and compare these metrics between the former NUFR and the former URGR. (ii) Evaluate the vegetation structure of URNP, particularly examining woody plant species DBH and regeneration potentials. By linking vegetation recovery patterns with habitat characteristics relevant to wildlife habitat use, this study provides ecological evidence to guide restoration priorities, adaptive management, and biodiversity conservation in recovering miombo protected areas in sub-Saharan Africa.

2.0. | Materials and Methods

2.1. | Study Area

This study was conducted in URNP, western Tanzania (05°00′–06°00′ S, 31°00′–32°00′ E; Fig. 1). Located approximately 100 km west of Tabora Municipality. The park is bordered by village lands to the north and east. The terrain is predominantly flat to gently undulating and is traversed by the perennial Ugalla and Walla rivers (Ngure, 2012). Managed by the Tanzania National Parks Authority, URNP forms part of the Ugalla–Moyowosi–Malagarasi Ramsar landscape (Kalumanga et al., 2016), highlighting its ecological importance within western Tanzania's savanna–wetland mosaic. The park also lies within the broader miombo woodland ecosystem and maintains ecological connectivity with the Katavi–Rukwa landscape through

contiguous woodlands, wetlands, and wildlife dispersal areas (Mulder et al., 2007; Ribeiro et al., 2020). Together, these interconnected conservation areas constitute one of Tanzania's largest remaining protected landscapes, supporting wildlife movement, ecological processes, and the persistence of biodiversity across western Tanzania (Giliba et al., 2022; Wilfred, 2018).

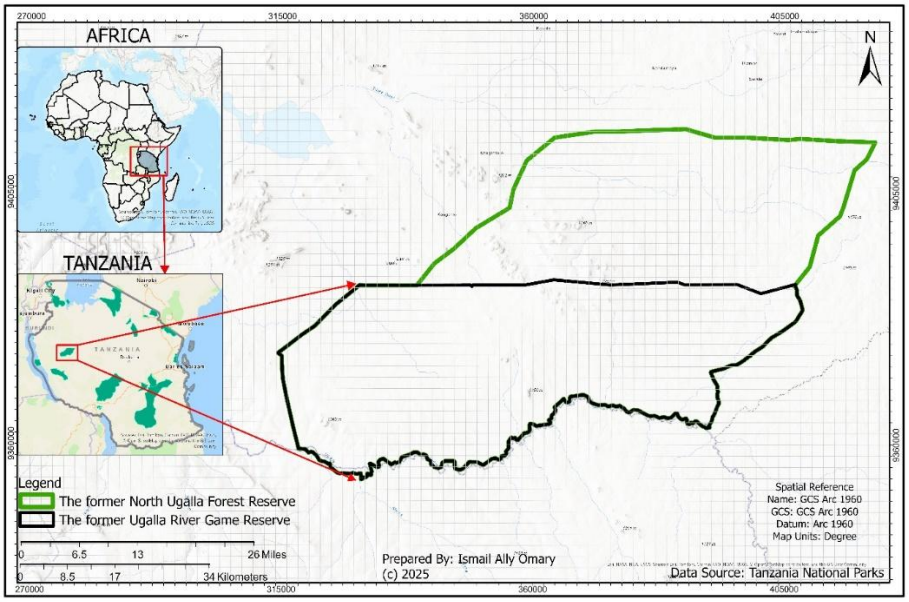

Fig 1. Map of Ugalla River National Park showing the location of the former NUFR relative to the former URGR.

The park experiences a tropical savanna climate characterized by a distinct wet season and a prolonged dry season. Annual rainfall ranges from approximately 800 to 1,200 mm, with marked interannual variability that strongly influences ecosystem productivity and vegetation dynamics (Archibald et al., 2013; Lehmann et al., 2011; Venter et al., 2018). Together with the nutrient-poor Orthic Ferralsols that dominate the Ugalla ecosystem (Sanchez et al., 2003), these climatic conditions shape vegetation structure, fire regimes, and ecological recovery processes.

Vegetation in URNP is dominated by miombo woodland, which covers nearly 80% of the park and represents the principal vegetation formation (Fig. 2). Riverine forests occur along permanent watercourses. At the same time, wooded grasslands and seasonally inundated *mbuga* grasslands occupy low-lying areas. The distribution and structure of these vegetation communities are regulated by interactions among rainfall variability, hydrological conditions, fire, and herbivory (Frost, 1996; Ribeiro et al., 2020).

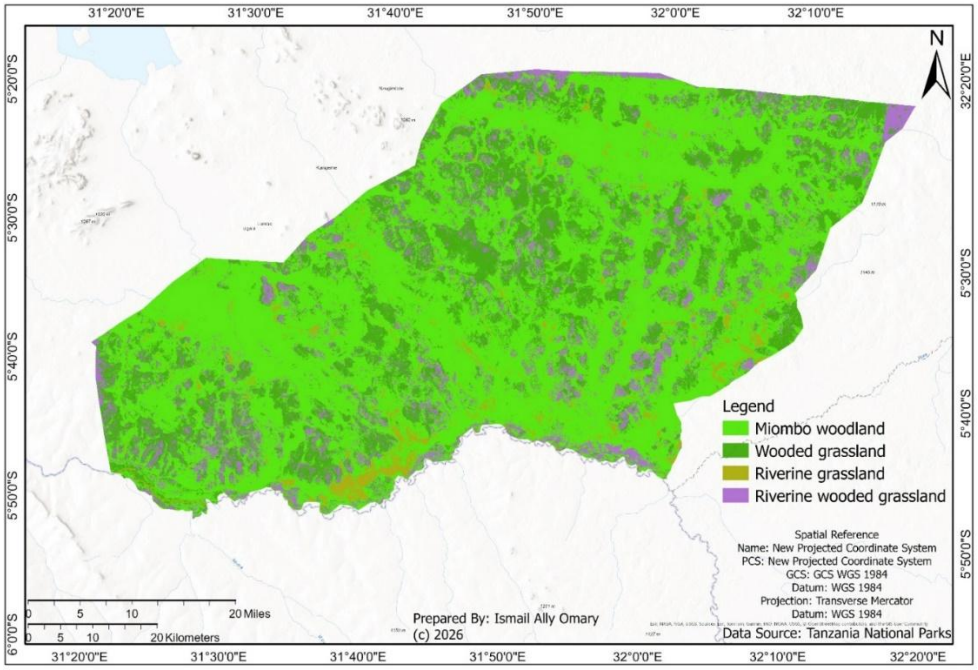

Fig 2. The vegetation type of Ugalla River National Park

The perennial Ugalla and Wala rivers constitute the principal hydrological features of URNP, sustaining an extensive network of floodplains, wetlands, and riparian habitats across the landscape. These hydrologically buffered environments maintain water availability and primary productivity throughout the prolonged dry season, creating localized areas of high habitat quality within the predominantly miombo-dominated ecosystem. Consequently, riverine and wetland habitats support greater structural complexity of vegetation and plant diversity than surrounding upland areas, while providing critical forage, water, and thermal refugia for wildlife (Ribeiro et al., 2020; Ryan et al., 2011). By sustaining key ecological processes during periods of climatic stress, the Ugalla–Wala River system enhances ecosystem resilience and serves as an important focal area for vegetation recovery, wildlife persistence, and recolonization in landscapes undergoing post-disturbance succession.

2.2. | Data Collection

A purposive sampling technique was used to select six existing management roads as transects to assess vegetation structure and floristic composition. Moreover, a comparative study design was adopted to collect data from a former NUFR and a URGR. These data were collected from August 21–24, 2024, along these fixed 30-km transects (Fig. 3). The transects were strategically located across the former URGR and the NUFR to capture variability in historical disturbance regimes.

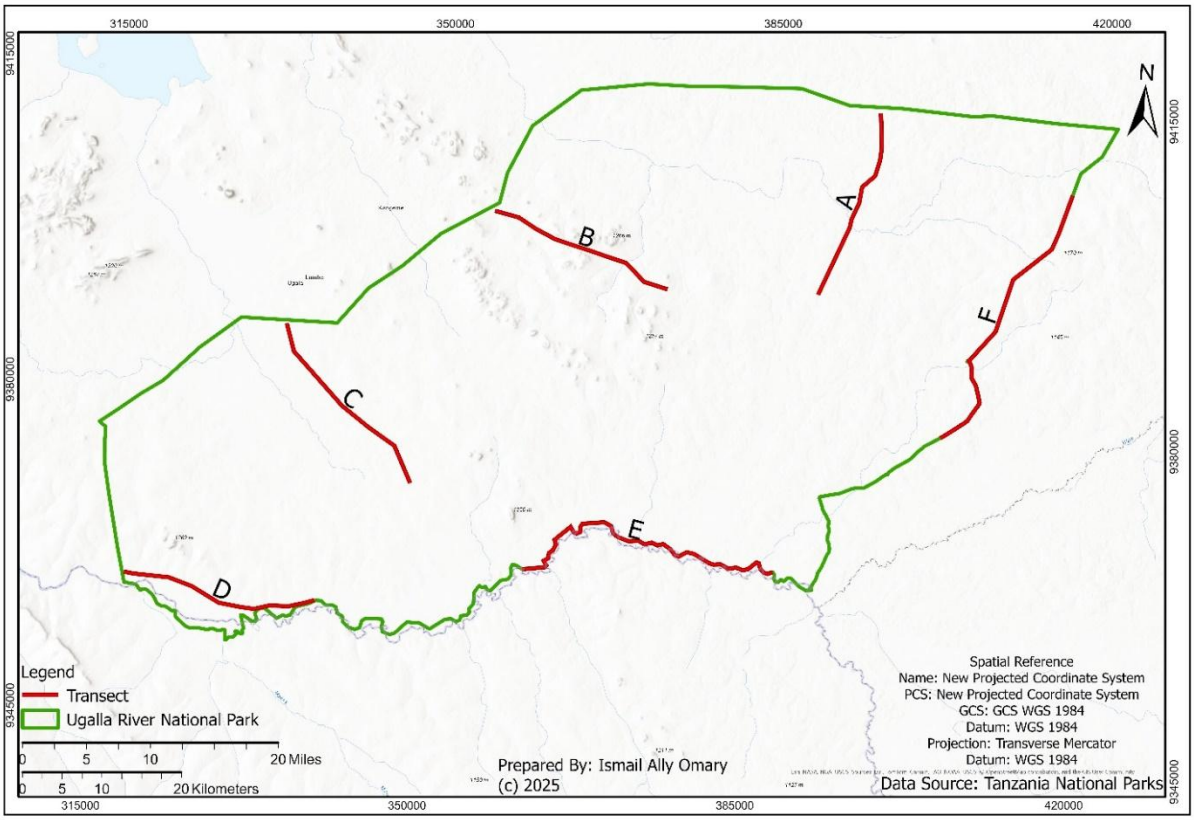

Fig 3. Map of Ugalla River National Park showing the location of the study transects.

Data were collected using the Modified Whittaker Plot Method (Stohlgren et al., 1995), as was applied in similar studies, particularly by Kikoti et al (2022). A total of 60 sampling plots, each 20 × 20m, were established at 10-km intervals along the transects. Within each plot, all tree species with DBH ≥ 10 cm were identified and measured, while shrubs and saplings were assessed in nested 5 × 5 m subplots located at the plot center. Herbaceous species were sampled in a nested 1 × 1 m quadrat. For each plot, species composition, abundance, stem density, basal area, and canopy cover were recorded. In addition, environmental and anthropogenic variables, including topography, indicators of human disturbance, and GPS coordinates, were documented to support analyses of vegetation patterns and recovery dynamics.

2.3. | Data Analysis

Plant data were quantitatively analyzed for species richness, stem density, basal area, and relative abundance. Species composition was summarized at the species level. Diversity was quantified using the Shannon–Wiener and Simpson indices to indicate compositional heterogeneity and recovery status. Species dominance was evaluated using relative abundance. Vegetation structure was assessed using basal area and DBH class distributions to infer regeneration and successional trajectories. To compare the estimated diversity, richness, evenness, and Sampson densities, we used an independent-samples t-test. All statistical analyses were conducted in R version 4.4.3.

3.0. | Results

3.1. |Floristic composition in URNP post gazettement

3.1.1. | Shannon diversity, richness, and evenness

Our study revealed clear differences in plant diversity between the former NUFR and the former URGR (Fig 4). Diversity indices were consistently higher in the former NUFR, indicating a richer and more evenly distributed plant community. Statistical analysis confirmed these patterns, with Shannon diversity (Welch's $t = 3.78$, $df = 23.6$, $p < 0.001$, $d = 1.47$), species richness (Welch's $t = 2.89$, $df = 18.7$, $p = 0.009$, $d = 1.15$), evenness (Welch's $t = 3.78$, $p < 0.001$, $d = 1.47$), and Simpson diversity (Welch's $t = 3.40$, $p = 0.003$, $d = 1.35$) all significantly higher in the former NUFR. (Welch's $t = 3.78$, $df = 23.6$, $p < 0.001$, $d = 1.47$). Species richness also differed significantly between the former management regimes (Welch's $t = 2.89$, $df = 18.7$, $p = 0.009$, $d = 1.15$), with the former NUFR supporting a greater number of species. Similarly, evenness and Simpson diversity were significantly greater in the former NUFR (Evenness: $t = 3.78$, $p < 0.001$, $d = 1.47$; Simpson: $t = 3.40$, $p = 0.003$, $d = 1.35$), indicating a more equitable distribution of individuals among species.

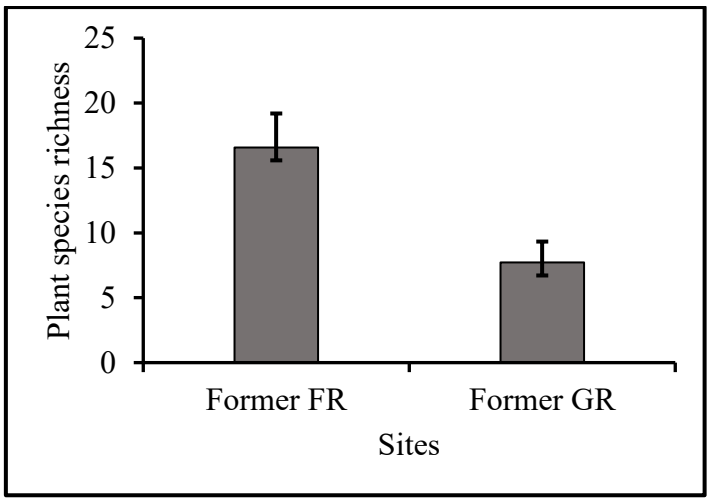

Fig 4. Comparison of species richness between the former NUFR and the former URGR.

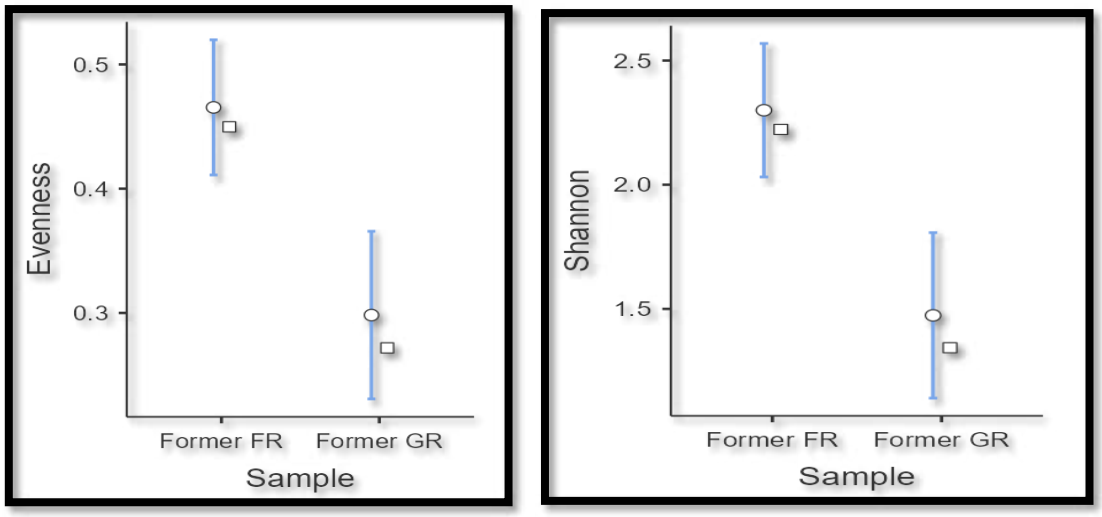

Fig 5. Comparison of species evenness and Shannon diversity between the former NUFR and the former URGR.

3.1.2. | Species dominance in URNP post-gazettement

Species abundance patterns differed markedly between the former NUFR and URGR (Table 1). In the former NUFR, abundance was distributed among several dominant miombo species, with *Brachystegia spiciformis* contributing 14.3% of all individuals recorded. In contrast, the former URGR was strongly dominated by *Terminalia sericea*, which accounted for one-third (33.3%) of all recorded individuals.

Table 1. Comparative species abundance between the former NUFR and the former URGR

	Former NUFR			Former URGR		
SN	Plant species	Abundance	RA (%)	Plant species	Abundance	RA (%)
1	*Brachystega spiciformis*	50	14.3	*Terminalia sericea*	330	33.30
2	*Pseudolachnostylis maprouneifolia*	25	7.2	*Combretum adenogonium*	80	8.07
3	*Brachystegia boehmii*	24	6.9	*Borassus aethiopum*	70	7.06
4	*Syzygium guineense*	23	6.6	*Crossopteryx febrifuga*	70	7.06
5	*Pterocarpus angolensis*	22	6.3	*Antidesma venosum*	40	4.04
6	*Diplorynchus condylocarpon*	21	6.0	*Pericopsis angolensis*	40	4.04
7	*Burkea africana*	20	5.7	*Terminalia mollis*	40	4.04
8	*Terminalia sericea*	16	4.6	*Searsia natalensis*	35	3.53
9	*Annona senegalensis*	12	3.4	*Diospyros abyssinica*	30	3.03
10	*Crossopteryx febrifuga*	9	2.6	*Kigelia africana*	30	3.03
11	*Hymenocardia acida*	9	2.6	*Vacheia seyal*	30	3.03
12	*Combretum zeyheri*	7	2.0	*Ochna macrocalyx*	25	2.52
13	*Julbernardia globiflora*	7	2.0	*Senna singuaena*	25	2.52

14	*Margaritaria discoides*	7	2.0	*Albizia petersana*	15	1.51
15	*Monotes africanus*	7	2.0	*Combretum molle*	15	1.51

RA = Relative abundance (%)

221

222 ### 3.2. | Vegetation structure in URNP post gazettement

223

224 #### 3.2.1. | Regeneration patterns in URNP post-gazettement

225 The current study found that the regeneration status of woody species was characterized
226 by three patterns: (1) good, (2) fair, and 3 (poor). The fair regeneration was predominantly
227 in both the former NUFR and former URGR (Figure 6). Nevertheless, the former NUFR
228 supported a higher number of species across all regeneration categories, whereas the
229 former URGR contained fewer species overall.

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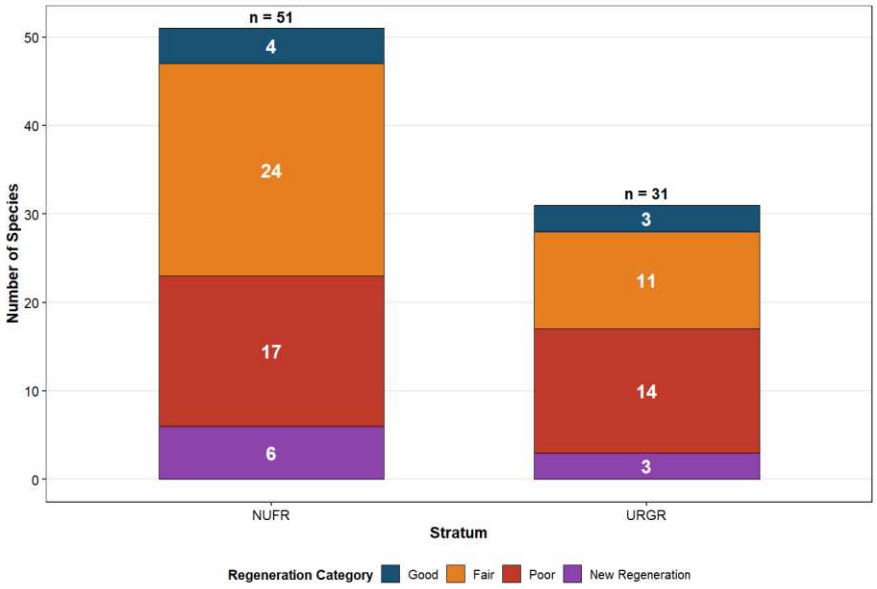

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232

233 **Fig 6.** Regeneration status of woody plant species in the former NUFR and former URGR,
234 classified as good, fair, poor, or no regeneration based on population structure.

235

236 ##### 3.2.1.1. | Good regeneration category

237 Following the overall regeneration assessment, the current study selected representative woody
238 species exhibiting good regeneration to illustrate their population structures (Figure 7). The
239 representative species maintained individuals across all growth stages, although the abundance
240 of each size class varied among species. Among these, *Brachystegia spiciformis* exhibited the
241 most pronounced regeneration pattern, recording the highest seedling density and a well-
242 represented population across successive growth stages.

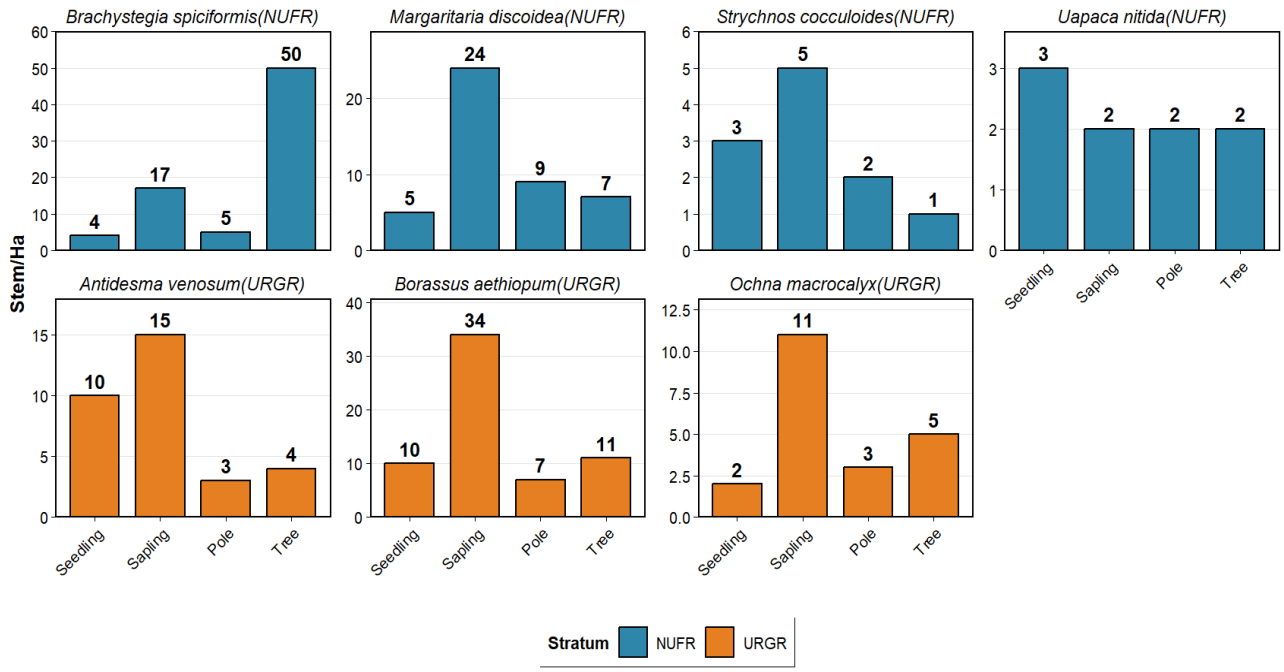

Fig 7. Population structure of representative woody species exhibiting good regeneration in the former North Ugalla Forest Reserve (NUFR) and former Ugalla Game Reserve (UGR).

3.2.1.2. | Fair regeneration category

Compared with the previous category, these species displayed less balanced population structures, with many exhibiting sparse or absent seedling stages and greater representation of saplings or mature trees. *Terminalia sericea* (URGR) showed the highest density of mature trees among the representative species (Figure 8)

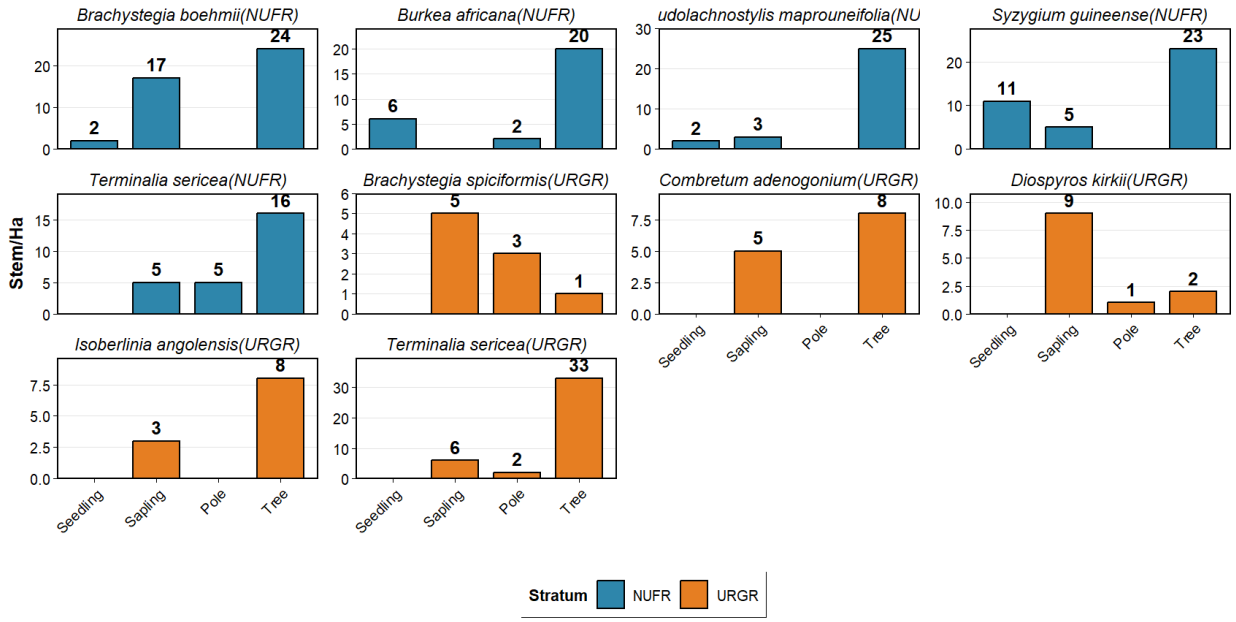

Fig 8. Population structure of representative woody species exhibiting fair regeneration in the former North Ugalla Forest Reserve (NUFR) and former Ugalla Game Reserve (UGR).

3.2.1.3. | Poor regeneration category

Unlike species with good and fair regeneration, these species were overwhelmingly dominated by mature trees, with seedlings, saplings, and poles being largely absent. This pattern was consistently observed in both the former NUFR and UGR, indicating limited or no recruitment into younger growth stages. Only a few representative species, such as *Crossopteryx febrifuga* in the former URGR, retained a small number of pole-sized individuals, while the remaining species were represented almost exclusively by mature trees

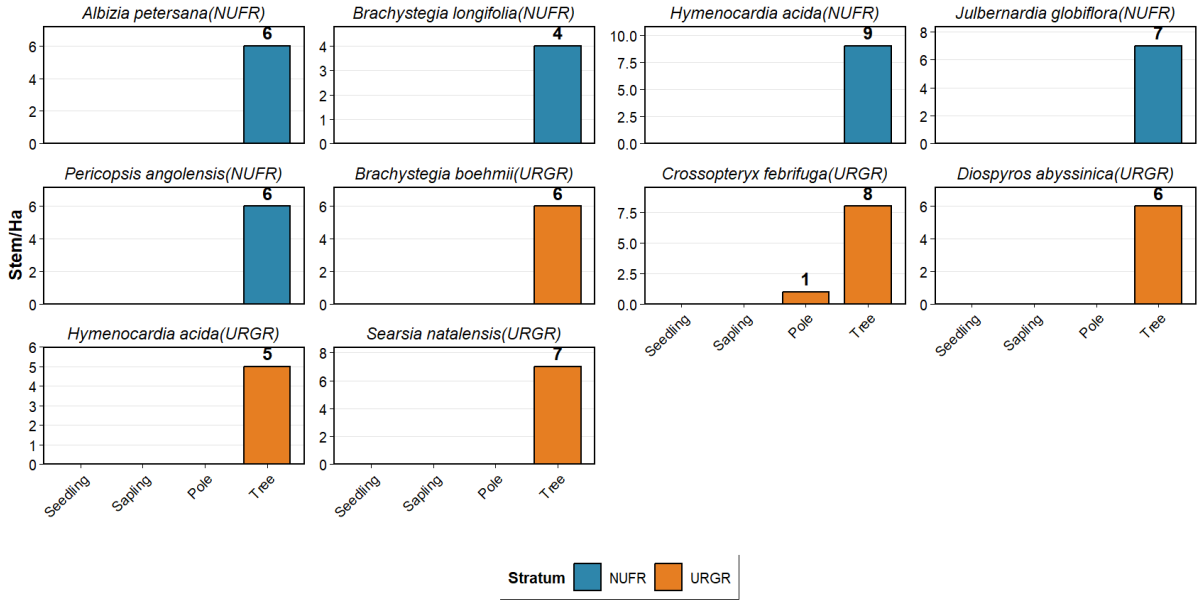

Fig 9. Population structure of representative woody species exhibiting poor regeneration in the former NUFR and former URGR.

3.2.2. DBH distributions in URNP post-gazettement

DBH distributions in both former NUFR and URGR were characterized by a predominance of individuals in smaller diameter classes. In the former NUFR, stem density was highest in the 5–9 cm class (298 stems ha^{-1}), followed by the 15–19 cm (118 stems ha^{-1}) and 10–14 cm (106 stems ha^{-1}) classes. Similarly, the former URGR showed the greatest density in the 5–9 cm class (125 stems ha^{-1}). Stem density declined progressively with increasing DBH classes in both areas, forming an inverse J-shaped distribution indicative of ongoing recruitment and regeneration.

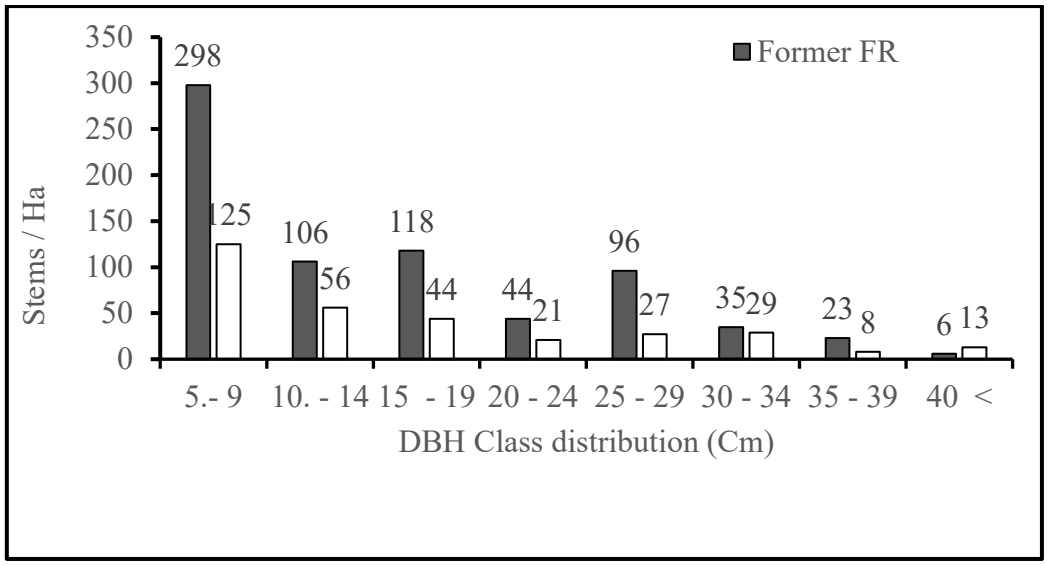

Fig 10. Diameter at breast height (DBH) class distribution of woody stems in the former NUFR and former URGR.

4.0. | Discussion

4.1. | Floristic Composition in URNP post-gazettement

4.1.1. | Shannon diversity, species richness, and evenness in URNP post-gazettement

Our assessment of floristic composition revealed marked differences between the two former protected areas, with the former NUFR supporting higher woody species richness, Shannon diversity, and evenness than the former URGR. These differences in floristic composition are important for evaluating vegetation recovery following gazettement, as species richness and diversity are widely used indicators of ecological recovery after disturbance reduction (Chazdon et al., 2007; Derroire et al., 2016). In miombo ecosystems, however, floristic composition is also strongly influenced by environmental conditions, fire regimes, and historical land use (Frost, 1996; Ribeiro et al., 2015). Therefore, we interpret these differences in the context of both disturbance history and inherent habitat characteristics, rather than solely as evidence of differential recovery success.

The significantly higher woody species richness, Shannon diversity, and evenness observed in the former NUFR suggest that this habitat supports a more structurally complex and compositionally balanced woody plant community than the former URGR. Diversity and evenness are widely regarded as indicators of ecosystem recovery because they reflect the re-establishment of multiple species and a more equitable distribution of individuals following reductions in anthropogenic disturbance (Chazdon et al., 2007; Derroire et al., 2016; Kikoti et al.,2022). Although the former NUFR and URGR experienced historical human disturbance prior to gazettement, the present diversity patterns suggest that legal protection has curtailed activities such as tree harvesting and other forms of habitat degradation, thereby allowing natural successional processes and vegetation recovery to proceed. These findings should, however, be interpreted alongside the habitat's intrinsic ecological characteristics.

The former NUFR is dominated by miombo woodland, one of Africa's most floristically diverse woodland ecosystems (Frost, 1996; Ribeiro et al., 2015). The structural heterogeneity of miombo woodlands, shaped by variation in canopy cover, soils, topography, and natural disturbance regimes, provides diverse ecological niches that support a rich assemblage of

woody plant species. In contrast, the former URGR comprises wooded grassland and floodplain habitats, where woody species diversity is naturally lower because tree recruitment is constrained by the combined effects of grasses, recurrent fire, and resource availability. High grass biomass promotes frequent fires that suppress the establishment of many woody species, thereby maintaining an open vegetation structure (Sankaran et al., 2005). Consequently, the lower diversity observed in the former URGR is consistent with its inherent ecological characteristics and does not necessarily indicate ecological degradation.

The diversity values recorded in the former NUFR are comparable with those reported from other miombo woodlands in eastern and southern Africa. For example, Shannon diversity indices ranging from approximately 2.8 to 3.4 have been reported in relatively intact or well-managed miombo ecosystems in Tanzania and Zambia, although diversity varies considerably with environmental conditions, management regime, and disturbance history (Giliba et al., 2011; Kalaba et al., 2013; Jew et al., 2016). The similarity of the diversity values observed in the former NUFR to those reported from other miombo woodlands suggests that the woody community retains the characteristic floristic composition of this ecosystem despite historical anthropogenic disturbance. From a conservation perspective, these findings are consistent with the expectation that gazettement, through reducing chronic anthropogenic disturbances such as tree harvesting and habitat degradation, has contributed to the maintenance of woody plant diversity. This interpretation is further supported by ecological restoration theory, which recognizes that the cessation of persistent human disturbance under protected-area management facilitates the maintenance and recovery of species diversity and community structure through natural successional processes (Chazdon et al., 2007; Derroire et al., 2016)

4.1.2. | Species dominance in URNP post-gazettement

The relative abundance patterns differed markedly between the two sites, reflecting both habitat-specific ecological conditions and the legacy of management prior to gazettement. In the former NUFR, no single species overwhelmingly dominated the community. Instead, abundance was distributed among several characteristic miombo woodland species, with *Brachystegia spiciformis* contributing 14.3% of all recorded individuals, followed by *Pseudolachnostylis maprouneifolia*, *Brachystegia boehmii*, and *Syzygium guineense*. This distribution of abundance among several characteristic canopy and sub-canopy species is consistent with the composition of relatively intact miombo woodlands, where *Brachystegia* and associated woody taxa commonly dominate community structure, without a single species monopolizing the woody assemblage (Frost, 1996; Chidumayo, 2013; Ribeiro et al., 2015). Although the former NUFR experienced anthropogenic disturbance prior to gazettement, the establishment of URNP likely reduced pressures such as tree harvesting and resource extraction, creating conditions favorable for the persistence and natural regeneration of characteristic miombo species. Consequently, the dominance of *Brachystegia* species is consistent with the maintenance or recovery of typical miombo woodland composition under protected-area management, although the present study does not directly assess temporal changes in vegetation (Chazdon et al., 2007; Derroire et al., 2016).

In contrast, the former URGR exhibited a markedly different abundance pattern, with *Terminalia sericea* accounting form one-third (33.3%) of all woody individuals recorded. This strong dominance is consistent with the ecological conditions characteristic of open wooded grassland and floodplain habitats, where vegetation structure is shaped by seasonal flooding, abundant grass biomass, and recurrent fire (Frost, 1996; Sankaran et al., 2005). These

environmental conditions favour disturbance-tolerant woody species capable of surviving repeated top-kill and regenerating through coppicing and basal resprouting, traits characteristic of *Terminalia sericea* (Louppe et al., 2008). Seasonal grass biomass provides continuous fine fuel that promotes recurrent fires, maintaining open vegetation and limiting the establishment of less fire-tolerant woody species (Bond & Keeley, 2005; Higgins et al., 2000). Consequently, despite the reduction in anthropogenic disturbance following gazettement, natural ecological processes are likely to continue favouring the numerical dominance of *T. sericea* within this habitat.

The contrasting abundance patterns therefore suggest that, while gazettement has likely reduced chronic anthropogenic disturbance, species composition and dominance remain strongly influenced by the inherent ecological characteristics of each area. The more equitable distribution of individuals among several characteristic woody species in the former NUFR is consistent with the composition of relatively intact miombo woodland (Frost, 1996; Chidumayo, 2013; Ribeiro et al., 2015). In contrast, the dominance of *T. sericea* in the former URGR reflects the persistence of a naturally open, fire-maintained woody community typical of wooded grassland ecosystems rather than evidence of ecological degradation (Sankaran et al., 2005; Bond & Keeley, 2005).

It is noteworthy that *Pterocarpus angolensis*, one of the most economically valuable and ecologically important tree species in miombo woodlands, was not among the dominant species in this study. *P. angolensis* is highly prized for its high-quality timber, which has made it a target for selective logging across miombo regions (Chidumayo, 1997).

The absence of *P. angolensis* from the most dominant species list may indicate several possibilities. First, historical selective logging may have significantly reduced this species' populations within URNP prior to gazettement, such that it now occurs at low densities and does not contribute substantially to relative density or dominance metrics. Second, coupling the first reason with the species' rarity even in undisturbed miombo woodlands, where it typically occurs as a scattered canopy tree rather than forming monodominant stands (Mojeremane & Lumbile, 2016), may have further exacerbated this.

Nevertheless, the low representation of *P. angolensis* raises conservation concerns. As a valuable timber species, it may require active management interventions following gazettement to ensure its persistence. Fire exclusion or prescribed burning regimes that promote germination, as well as protection against illegal harvesting, may be necessary for populations to recover (Mojeremane & Lumbile, 2016; Mehl et al., 2010).

4.1.3. | Regeneration patterns in URNP post-gazettement

Woody species regeneration provides one of the most reliable indicators of vegetation persistence and resilience because it reflects the capacity of plant populations to replace mature individuals and maintain community structure over time (Shankar, 2001; Dhaulkhandi et al., 2008; Khumbongmayum et al., 2006). The predominance of species exhibiting fair regeneration in both the former NUFR and URGR suggests that natural regeneration is occurring across much of the park, although recruitment success varies considerably among species. Such variation is expected because regeneration is influenced by species-specific life-history traits, disturbance regimes, and local environmental conditions, including fire, herbivory, soil characteristics, and moisture availability (Chidumayo, 2013; Frost, 1996). The

greater number of species recorded in each regeneration category in the former NUFR further supports the conclusion that vegetation recovery is more advanced in this section of the park.

Species classified as exhibiting good regeneration displayed individuals across all developmental stages, indicating continuous recruitment and successful progression from seedlings to mature trees. Population structures characterized by abundant seedlings, saplings, and adults are widely interpreted as evidence of stable or self-sustaining populations capable of maintaining themselves under prevailing environmental conditions (Shankar, 2001; Khumbongmayum et al., 2006). Among the representative species, *Brachystegia spiciformis* showed particularly strong regeneration, with abundant seedlings and individuals represented throughout successive growth stages. As one of the principal canopy-forming species of miombo woodlands, successful regeneration of *B. spiciformis* is ecologically significant because it underpins woodland persistence, canopy development, and the maintenance of ecosystem structure and function (Frost, 1996; Chidumayo, 2013; Ribeiro et al., 2015)

In contrast, species exhibiting fair regeneration showed less balanced population structures, with recruitment concentrated in saplings or mature trees and comparatively few seedlings. Such patterns may indicate episodic recruitment, where successful establishment occurs only during favorable climatic conditions or following temporary reductions in disturbance (Shankar, 2001; Khumbongmayum et al., 2006). Recruitment in tropical woodlands is strongly influenced by rainfall variability, fire frequency, herbivory, and competition for resources, all of which can limit seedling survival even when mature seed-producing individuals remain abundant (Frost, 1996; Chidumayo, 2013; Sankaran et al., 2005). Consequently, these species may require longer recovery periods before stable population structures are fully re-established.

Species classified as exhibiting poor regeneration were largely represented by mature trees with little or no recruitment into younger size classes. Populations dominated by aging individuals are generally considered vulnerable because they depend on mature trees without adequate replacement by younger cohorts (Khumbongmayum et al., 2006; Dhaulkhandi et al., 2008). Similar regeneration limitations have been documented in disturbed African woodlands, where repeated fire, grazing, seed limitation, and altered microsite conditions constrain seedling establishment despite the continued persistence of adult trees (Frost, 1996; Chidumayo, 2013). If recruitment remains limited, these species may gradually decline despite the park's current protection status, highlighting the importance of long-term monitoring to evaluate future population trajectories.

4.1.4. | Diameter-class distributions post-gazettement

Despite variation among species, the overall DBH distribution of woody vegetation exhibited a clear inverse J-shaped pattern at both sites, characterized by high densities of small-diameter stems and progressively fewer large trees. Such inverse J-shaped diameter distributions are widely regarded as indicative of continuous recruitment and self-sustaining woodland populations because they reflect the ongoing replacement of mature trees by younger cohorts (Meyer, 1952; Oliver & Larson, 1996). The more pronounced representation of smaller diameter classes in the former NUFR is consistent with its higher species diversity and stronger regeneration patterns, suggesting more favorable conditions for woody recruitment under current management. This pattern aligns with expectations for protected woodlands where reductions in chronic anthropogenic disturbance promote the establishment and survival of younger individuals (Frost, 1996; Chidumayo, 2013), although inherent habitat characteristics

such as soil properties, moisture availability, and historical land-use legacies also contribute to differential recruitment success (Dupouey et al., 2002; Kraft et al., 2015).

Interestingly, the community-level inverse J-shaped distribution contrasts with the poor regeneration observed for several individual species. This apparent discrepancy indicates that, while woodland regeneration is occurring at the community level, recovery is not uniform across all taxa. Successful recruitment of dominant or disturbance-tolerant species may maintain an apparently stable stand structure and overall diversity even when other species remain recruitment-limited (van Gemerden et al., 2003; Chidumayo, 2013). Such demographic asynchrony is a well-documented feature of tropical forest dynamics, in which canopy gaps, seed-dispersal limitations, and differential shade tolerance create contrasting regeneration niches (Hubbell et al., 1999). These contrasting patterns highlight the importance of integrating community-level structural assessments with species-specific regeneration analyses when evaluating ecosystem recovery and long-term vegetation persistence.

5. | Conclusion

This study provides one of the first assessments of floristic composition and vegetation structure in Ugalla River National Park during the early post-gazettement period. The findings indicate that passive ecological recovery is underway, as evidenced by relatively high woody plant diversity, widespread natural regeneration, and inverse J-shaped diameter-class distributions characteristic of regenerating woodlands. However, recovery was not uniform across the park. The former North Ugalla Forest Reserve supported greater species diversity, richer woody plant communities, and stronger regeneration than the former Ugalla River Game Reserve, reflecting differences in historical management and inherent habitat characteristics. Species composition also differed markedly between the two areas, with characteristic miombo woodland species dominating the former NUFR and disturbance-tolerant species characterizing the former URGR.

Although the overall vegetation structure suggests a positive recovery trajectory, the poor regeneration of several woody species, particularly those of high ecological and conservation value, indicates that some populations may remain vulnerable despite improved protection. Continued ecological monitoring is therefore necessary to determine whether these species recover naturally or require targeted management interventions. Overall, this study establishes an important ecological baseline for assessing long-term vegetation dynamics and provides evidence to support adaptive management and conservation planning in Ugalla River National Park and other recovering miombo woodland protected areas in sub-Saharan Africa

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ETHICAL STATEMENT

This study was conducted in accordance with the laws and regulations of the United Republic of Tanzania. Research approval was obtained from the Tanzania Commission for Science and Technology (COSTECH) under Permit No**.** CST-00001650-2025-00064 and from the Tanzania Wildlife Research Institute (TAWIRI) under Reference No. AB.235/325/01 "A"/133**.** All fieldwork was undertaken with the authorization of TANAPA and complied with its operational guidelines and regulations.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study will be deposited in a publicly accessible open-access repository. Until the dataset is publicly available, the data may be obtained from the corresponding author upon reasonable request.

CLINICAL TRIAL NUMBER

Not applicable

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