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Diversity and composition of anurans on Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines

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Abstract. *Flores ABA, Mondejar EP, Caballero EB, Maceda JN, Olowa LF, Nuñeza OM. 2025. Diversity and composition of anurans on Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines. Biodiversitas 26: 3769-3780.* Mount (Mt.) Gutom Protected Landscape is among the last remaining natural forests and serves as one of the most critical watersheds in Zamboanga del Norte, Philippines. Despite its ecological importance, no comprehensive studies on anuran species have been conducted in the area, leaving a significant gap in our understanding of the area's amphibian biodiversity and its conservation needs. This study investigates the species composition, abundance, and conservation status of anurans in the Mt. Gutom Protected Landscape. An opportunistic sampling method was employed at four sites: Sikitan, Malikas, Lower Gutom, and Upper Gutom. A total of 269 individuals representing 19 species from six families were recorded, with the highest species richness observed in Sikitan and Malikas. Notably, 12 species (63.16%) are endemic to the Mindanao Faunal Region, while three (15.79%) species are Philippine endemics, and the remaining are native (21.05%) to the country but more widely distributed. The Near Threatened species *Limnonectes magnus* was recorded as the most abundant and dominant species. According to the Bray-Curtis similarity analysis, two distinct site clusters (Sikitan-Malikas and Lower-Upper Gutom) indicate habitat differences that influence species distribution. SIMPER analysis confirmed that *L. magnus* contributed significantly to observed dissimilarities. Diversity indices revealed substantial variation: Malikas had the highest Shannon diversity index (H′: 2.328) and the lowest dominance index (D: 0.1208), reflecting a balanced and less disturbed habitat. Sikitan followed closely (H′: 2.205, D: 0.1431). In contrast, Lower Gutom (H′: 1.819, D: 0.2535) and Upper Gutom (H′: 1.489, D: 0.3399) exhibited higher dominance and lower diversity, suggesting anthropogenic pressures. These results highlight the ecological importance and site-specific vulnerabilities of Mt. Gutom's anuran communities, emphasizing the need for urgent conservation interventions, including habitat protection, continued monitoring, and community-based stewardship programs to safeguard these endemic and threatened amphibians.

Keywords: Abundance, conservation, endemic, frogs, Mindanao

INTRODUCTION

Amphibians, particularly anurans (frogs), play an important ecological role in maintaining ecosystem balance, functioning as both predator and prey (Cortéz-Gómez et al. 2015; Tripathi et al. 2024). Globally, they are among the most threatened vertebrate groups, facing extinction risks from combined pressures such as habitat destruction, climate change, pollution, invasive species, and disease (Reyda et al. 2020; Rodríguez-Rodríguez et al. 2020; Luedtke et al. 2024). Southeast Asia harbors exceptionally high amphibian diversity and endemism—81% of species occur nowhere else (Pratihar et al. 2014). However, global conservation attention remains limited due to insufficient distribution and population data (Rowley et al. 2010). Many species are classified as Data Deficient (Nesi et al. 2023), meaning the true number of threatened species is likely underestimated (Hoffmann et al. 2010; Alcala et al. 2012; Pratihar et al. 2014). Without accurate risk assessments, conservation prioritization becomes challenging (Nowakowski et al. 2024). Thus, studies on species abundance, demography, and ecological traits are vital for evidence-based conservation in the region (Nori et al. 2018).

The Philippines, with 116 anuran species—about 85% endemic—represents a center of herpetofaunal diversity in Southeast Asia (Diesmos et al. 2002, et al. 2015). The country's archipelagic structure, varied topography, and habitat heterogeneity have driven high speciation and endemism (Diesmos and Brown 2011; Brown et al. 2013). Many species occupy narrow ecological niches in isolated islands or mountain ranges, making them highly susceptible to environmental change and human disturbance (Fordham and Brook 2010; Alcala et al. 2012; Graham et al. 2017; Flores et al. 2024a; Gojo-Cruz et al. 2024). Significant population declines and local extirpations have been observed, especially in poorly studied areas (Lal and Nadim 2021). Philippine anuran diversity remains incompletely documented, particularly in remote locations lacking systematic surveys (Meneses et al.

2024), underscoring the need for more field research, updated threat assessments, and locally tailored conservation actions.

Mindanao Island, in Southern Philippines, contains diverse ecosystems supporting high amphibian richness. Recent research has examined frog diversity (Delima-Baron et al. 2019, et al. 2022; Venturina et al. 2020, et al. 2023; Baron et al. 2021; Galolo 2021; Pitogo et al. 2021), ecology (Warguez et al. 2013; Jabon et al. 2019; Plaza et al. 2021; Lama and Senarillos 2023), and larval development and morphology (Flores et al. 2023a, b). However, these studies have concentrated on well-known mountain systems, leaving the Zamboanga Peninsula relatively understudied in terms of anuran diversity.

One such understudied site is Mount (Mt.) Gutom Protected Landscape in Zamboanga del Norte, located in President Manuel A. Roxas municipality. This ecologically important mountain retains significant natural forest cover, essential for diverse flora and fauna. Habitats include dipterocarp forests with old-growth and secondary-growth stands (Abijay et al. 2023), which provide breeding sites, foraging areas, and refuge for anurans. Despite its biodiversity, Mt. Gutom faces environmental threats that endanger its ecosystems. The Department of Environment and Natural Resources (DENR) has called for stricter protection and long-term management (Tome et al. 2019). Existing research here is minimal, with studies limited to bats (Lama et al. 2023), butterflies (Abijay et al. 2023), and odonata (Dicol et al. 2024). No published studies have addressed frog diversity, and little is known about anurans' ecological needs or habitat preferences. This lack of information hampers conservation planning and prediction of responses to environmental change.

Addressing these gaps is critical. Anurans are sensitive bioindicators that reflect ecosystem health (Kurnianto et al. 2024). Understanding their diversity and ecology in Mt. Gutom will contribute to both local and global amphibian conservation. This study aims to: (i) document species composition, abundance, and richness of frogs in Mt. Gutom; (ii) determine their conservation and distribution status; and (iii) analyze distribution and diversity patterns, and assess threats to their persistence across sites. Documenting anuran species in Mt. Gutom will fill existing data gaps, guide conservation strategies, and strengthen broader efforts to address amphibian declines and safeguard unique ecosystems.

MATERIALS AND METHODS

Study area

The study was conducted on Mount Gutom Protected Landscape. It is geographically located on the southern tip of the Municipality of President Manuel A. Roxas, in the province of Zamboanga del Norte, Philippines (8°20'30.068"N and 123°10'22.368"E). The highest elevation of the mountain is at least 1,199 meters above sea level (m asl) (Figure 1). The sampling sites considered both secondary forests and agroecosystems.

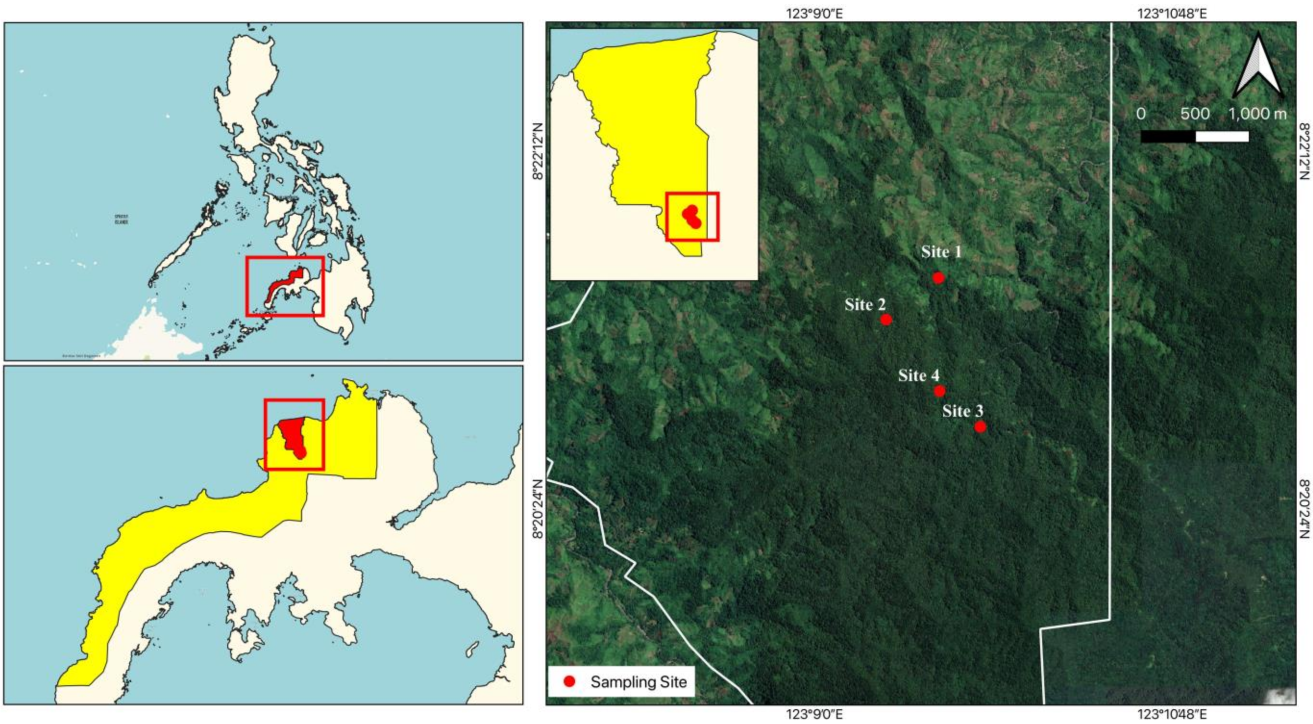

Figure 1. Geographical location of the study area showing the different sampling sites (red dots) in the Municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines. The inset maps indicate the regional context of the Philippines and Zamboanga Peninsula

Figure 2. Representative habitat photographs of the four sampling sites in the Mt. Gutom Protected Landscape, Municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines: A. Site 1: Sikitan, B. Site 2: Malikas, C. Site 3: Lower Gutom, and D. Site 4: Upper Gutom. All sites are characterized by varying degrees of forest structure and vegetation density

Description of sampling sites

Sampling sites (Figure 2) were selected based on the vegetation type and ecological features in each area. Site 1: Sikitan, which is located in Sitio Tonggon (8.3594° N; 123.1604° E; 672.9 m asl), lies within the buffer zone of the protected area and features a secondary lowland dipterocarp forest along the Sikitan River. Site 2: Malikas (8.3559° N; 123.1560° E; 844 m asl), is also classified as a secondary lowland dipterocarp forest and includes emerging tree species such as *Ziziphus talanai* (locally known as "balakat-gubat"). The terrain here is flat to gently undulating and is located approximately one kilometer from the Tonggon River. Visible anthropogenic disturbances can be observed at the site, including illegal logging, foraging, fuelwood extraction, resin extraction, and the presence of invasive species such as *Leucaena leucocephala*, *Elephantopus mollis*, and *Mikania cordata*. Site 3: Lower Gutom, situated in Barangay Panampalay (8.3469° N; 123.1639° E; 772 m asl), within the Mt. Gutom Protected Landscape. It is approximately 50 meters from the Piao River and is characterized by a secondary lowland forest, with aroids dominating the ground layer and scattered emergent tree species. Lastly, Site 4: Upper Gutom (8.3499° N; 123.1605° E; 890 m asl), features a dipterocarp forest adjacent to riparian zones and is dominated by *Shorea* spp. with emergent *Z. talanai* trees.

Collection, processing, and identification of specimens

Prior to conducting the study, sampling and collection permit was granted by the Department of Environment and Natural Resources, Region 9, with the Wildlife Gratuitous Permit No. R9-07-2021. Field sampling was conducted from 12-22 April 2022 and 6-22 December 2022. Each site was surveyed for seven (7) consecutive days, with daily sampling during daylight hours (1000-1600 hr) and at night (1800-2200 hr), totaling approximately ten (10) survey hours per day. Across all surveyed sites, a total of 320 man-hours was expended. This cumulative effort accounts for the number of individuals involved, the number of sites surveyed, and the time spent per day, to ensure consistency in sampling coverage across spatial and temporal scales.

Opportunistic sampling was employed to intensively sample the arboreal, ground, and subterranean species of the chosen sampling sites. Sampling in the arboreal habitats involved inspecting bird's nest fern (*Asplenium nidus*), cavities in trees, epiphytes on tree trunks, and "pakpak lawin" (*Drynaria quercifolia*). Samplings in subterranean habitats involves removing rocks, rotting logs, and bank substrates along rivers and streams. All associated microhabitats of anurans served as the basis for selecting sampling sites. Captured specimens were photographed, collected, and processed in the field station and measured for key features like snout-vent length, body length, and weight. They were then identified using field guides by Alcala and Brown (1998), Diesmos et al. (2015), and other references on Philippine amphibians. Moreover, specimens identified in the field were marked and released back at their site of capture. On the other hand, voucher specimens were collected for unidentified specimens or potentially new species. Furthermore, the distribution and conservation status of anurans were determined based on the updated IUCN Red List of Threatened Species (IUCN 2025).

Data analysis

To assess the similarity in species composition among anurans and determine the species that contributed to the similarity between sampling sites, we employed the Bray-Curtis similarity and the Similarity Percentage (SIMPER) analysis through the abundance data (number of individuals recorded) of species in each site using the BioDiversity Pro software (McAleece et al. 1997). On the other hand, species diversity indices such as species richness (S), Shannon-Wiener (H'), Simpson's (D) for dominance and evenness (J') were calculated between sampling sites using the Paleontological Statistics software version 3.06 (Hammer and Harper 2001).

RESULTS AND DISCUSSION

Species composition and abundance

A total of 269 individuals were recorded during the research period, representing 19 species from 6 families. The family Rhacophoridae was the most represented in terms of the number of species recorded, with 6 species: *Leptomantis bimaculatus, Philautus acutirostris, Philautus surdus, Philautus worcesteri, Polypedates leucomystax,* and *Rhacophorus pardalis.* This was followed by family Dicroglossidae comprising 4 species: *Limnonectes leytensis, Limnonectes magnus, Limnonectes parvus,* and *Occidozyga laevis.* Additionally, the Family Bufonidae included 3 recorded species: *Ansonia mcgregori, Ansonia muelleri,* and *Pelophryne brevipes.* Lastly, the Family Megophryidae (*Leptobrachium lumadorum* and *Pelobatrachus stejnegeri*), Microhylidae (*Chaperina fusca* and *Kalophrynus sinensis*), and Ranidae (*Pulchrana grandocula* and *Staurois natator*) were represented by at least 2 species (Table 1). The most abundant species in the area are typically stream-dwelling, such as *L. magnus* (33.46%), *S. natator* (16.36%), *A. muelleri* (11.15%), and *P. grandocula* (10.78%). These are followed by *P. stejnegeri* (4.46%), *L. leytensis* (4.09%), *O. laevis* (3.35%), *A. mcgregori* (2.97%), *P. surdus* (2.60%), *L. bimaculatus* (2.23%), and *K. sinensis* (2.23%). Some species are quite rare, with fewer than five individuals recorded, including *L. lumadorum* and *P. worcesteri* (1.12%), *P. leucomystax* and *R. pardalis* (0.74%), and *P. acutirostris, C. fusca,* and *P. brevipes* (0.37%).

The site with the highest number of species was found to be in both Sikitan (Site 1) and Malikas (Site 2), having 13 different species recorded; this was followed by Lower Gutom (Site 3) with only 11 species and Upper Gutom (Site 4) with 9 species recorded (Figure 3). The species recorded in these sites were primarily found in aquatic ecosystems, as well as in substrate or ground litter and arboreal microhabitats. Notably, the species that can be found on rocks along the streams and rivers were *A. muelleri, A. mcgregori, S. natator, L. magnus, L. leytensis,* and *L. parvus.* Some species are also found on decaying logs (*L. lumadorum*), on leaf litter (*P. stejnegeri*), on trees, or above ground, including *L. bimaculatus, P. acutirostris, P. worcesteri, P. surdus, P. leucomystax* and *R. pardalis.*

The remarkable species richness observed in Sikitan (Site 1) and Malikas (Site 2) was possibly associated with the presence of different microhabitats that could support the habitat and physiological requirements of anurans in the area. For instance, *Ansonia* spp. and *L. magnus* have been reported to occur in montane habitats and lowlands immediately adjacent to mountains with high-gradient stream flow (Sanguila et al. 2016). In this study, *Ansonia* spp. and *L. magnus* were commonly observed on rocks along the Sikitan River and along the streams of Malikas. This implies that the presence of water bodies is vital for *Ansonia* spp. and *L. magnus,* as part of their development occurs in streams, and any changes in water quality will subsequently affect their survival and that of other water-dependent anuran species.

Moreover, most of the recorded anurans in Mt. Gutom Protected Landscape belong to the family Rhacophoridae, with both sampling sites 1 and 2 recording three species each, accounting for 31.58% of the total number of recorded species. Some species in the family Rhacophoridae exhibit direct development and independence from standing water for larval development (Chen et al. 2020). This mode of reproduction, which involves ovipositing arboreally, enables this species to avoid unfavorable environmental conditions, such as temperature and moisture, that may affect embryonic development (de Lima et al. 2016) and enables their persistence in both the forest canopy and shrub layers (Hertwig et al. 2013). Apart from this, it also buffers them from the dependence of standing water and provides a mechanism for survival in fragmented habitats (Meegaskumbura et al. 2019). In contrast, the high relative abundance of some stream-dependent species such as the *A. muelleri, A. mcgregori, L. magnus,* and *S. natator* demonstrates the crucial role of water bodies such as streams and riparian corridors in maintaining local populations of anurans (Surasinghe and Baldwin 2015; Almeida et al. 2020; Covarrubias et al. 2021; Graziano et al. 2022). Studies also suggest that these species are considered good bioindicators of stream health (Aureo and Bande 2017; Torre and Nuñeza 2021).

The notable high species richness and the significant proportion of both Mindanao and Philippine endemic species in Mt. Gutom are comparable to other biodiversity assessments around Mindanao's montane and riparian ecosystems. This includes the study conducted in Mt. Kalo-Kalo with only 12 species (Torre and Nuñeza 2021); Mt. Matutum and Mt. Kitanglad only recorded 13 species (Nuñeza et al. 2017; Baron et al. 2021); Mt. Pantaron Range with at least 18 species recorded (Coritico et al. 2018), and other mountain areas in the Philippines like the

Central Panay Mountain Range, which accounts for at least 11 species of frogs (Flores et al. 2024b). Even though the sites were only assessed in selected areas (particularly in low elevation), the species in Mt. Gutom were recorded higher than in the other studies conducted in other mountain areas. For instance, the species richness, particularly in Sikitan and Malikas, reflects the presence of microhabitats that are vital for anuran breeding and shelter. So, the dominance of rhacophorid species aligned with the findings of some studies conducted wherein similar trends have also been recorded specifically in Mt. Kalo-Kalo (Torre and Nuñeza 2021), Mt. Kitanglad (Baron et al. 2021), Mt. Hilong-hilong (Plaza and Sanguila 2015), Mt. Hamiguitan (Supsup et al. 2017), and some green spaces in Davao City (Delima-Baron et al. 2022), highlighting that microhabitat heterogeneity underpins anuran diversity.

Species distribution and conservation status

A total of 12 (63.16%) Mindanao Faunal Region Endemic (MFRE) species were recorded in Mount Gutom Protected Landscape, including *A. muelleri, A. mcgregori, K. sinensis, L. bimaculatus, L. lumadorum, L. magnus, L. parvus, P. brevipes, P. acutirostris, P. worcesteri, P. stejnegeri*, and *P. grandocula.* In addition, three Philippine Endemic (PE) species were also observed (15.80%), including: *L. leytensis, P. surdus*, and *S. natator.* The area also supports four native (N) species (21.05%), namely *O. laevis, C. fusca, P. leucomystax*, and *R. pardalis.* Most of the recorded anuran species (94.73%) are classified as Least Concern by the International Union for Conservation of Nature (IUCN), with only one species, *L. magnus*, listed as Near Threatened (Table 2).

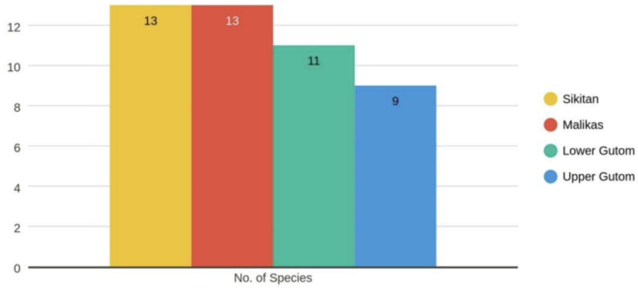

Figure 3. Species richness of anurans recorded across the four sampling sites in Mount Gutom Protected Landscape, Municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines. The sites include Sikitan (Site 1), Malikas (Site 2), Lower Gutom (Site 3), and Upper Gutom (Site 4). Richness is represented by the total number of anuran species recorded per site during field surveys

Table 1. Species composition and relative abundance of anurans from four sampling sites in Mount Gutom Protected Landscape, Municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines. Species are arranged by family, with the total number of individuals (N) and relative abundance (%) indicated. Sampling sites include Site 1: Sikitan, Site 2: Malikas, Site 3: Lower Gutom, and Site 4: Upper Gutom

Species	Common name	Sampling sites				N	Rel. abundance (%)
		S1	S2	S3	S4		
Bufonidae							
Ansonia mcgregori	Mcgregor's Stream Toad	4	2	1	1	8	2.97%
Ansonia muelleri	Mueller's Stream Toad	12	5	6	7	30	11.15%
Pelophryne brevipes	Zamboanga Flathead Toad	0	1	0	0	1	0.37%
Dicroglossidae							
Limnonectes leytensis	Leyte Swamp Frog	6	2	3	0	11	4.09%
Limnonectes magnus	Mindanao Fanged Frog	7	0	35	48	90	33.46%
Limnonectes parvus	Philippine Small-Disked Frog	1	2	1	0	4	1.49%
Occidozyga laevis	Philippine Oriental Frog	4	0	3	2	9	3.35%
Megophryidae							
Leptobrachium lumadorum	Mindanao Litter Frog	1	2	0	0	3	1.12%
Pelobatrachus stejnegeri	Mindanao Horned Frog	3	3	5	1	12	4.46%
Microhylidae							
Chaperina fusca	Saffron Bellied Frog	0	1	0	0	1	0.37%
Kalophrynus sinensis	Philippine Sticky Frog	0	0	0	6	6	2.23%
Rhacophoridae							
Leptomantis bimaculatus	Mindanao Flying Frog	1	0	3	2	6	2.23%
Philautus acutirostris	Pointed-Snouted Tree Frog	0	1	0	0	1	0.37%
Philautus surdus	Luzon Bubble-Nest Frog	0	5	2	0	7	2.60%
Philautus worcesteri	Smooth-Skinned Tree Frog	0	3	0	0	3	1.12%
Polypedates leucomystax	Common Southeast Asian Tree Frog	2	0	0	0	2	0.74%
Rhacophorus pardalis	Harlequin Tree Frog	2	0	0	0	2	0.74%
Ranidae							
Pulchrana grandocula	Big-Eyed Frog	4	4	8	13	29	10.78%
Staurois natator	Mindanao Splash Frog	17	10	9	8	44	16.36%
Total no. of individuals		64	41	76	88	269	100%

Table 2. Conservation status (IUCN 2025) and distribution status of anuran species recorded from Mount Gutom, Protected Landscape, Municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines

Species	Conservation status (IUCN 2025)	Distribution status
Bufonidae		
Ansonia mcgregori	LC	MRFE
Ansonia muelleri	LC	MRFE
Pelophryne brevipes	LC	MRFE
Dicroglossidae		
Limnonectes leytensis	LC	PE
Limnonectes magnus	NT	MRFE
Limnonectes parvus	LC	MFRE
Occidozyga laevis	LC	N
Megophryidae		
Leptobrachium lumadorum	LC	MRFE
Pelobatrachus stejnegeri	LC	MRFE
Microhylidae		
Chaperina fusca	LC	N
Kalophrynus sinensis	LC	MRFE
Rhacophoridae		
Leptomantis bimaculatus	LC	MRFE
Philautus acutirostris	LC	MRFE
Philautus surdus	LC	PE
Philautus worcesteri	LC	MRFE
Polypedates leucomystax	LC	N
Rhacophorus pardalis	LC	N
Ranidae		
Pulchrana grandocula	LC	MRFE
Staurois natator	LC	PE

Legend: PE: Philippine Endemic, MFRE: Mindanao Faunal Region Endemic, N: Native, LC: Least Concern, NT: Near Threatened

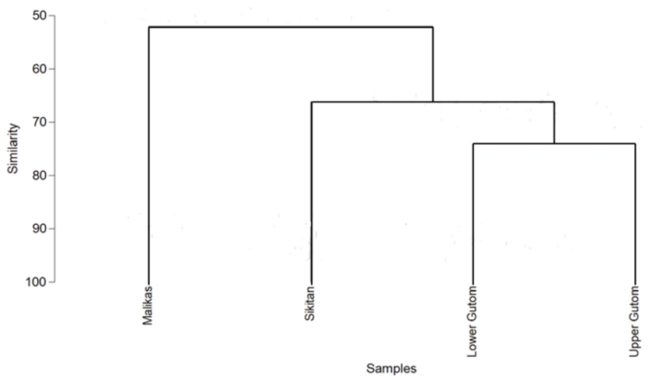

Figure 4. Bray-Curtis similarity dendrogram showing the faunal resemblance among the four anuran sampling sites in Mount Gutom, Zamboanga del Norte, Philippines. The cluster analysis was performed using BioDiversity Pro software based on species composition and abundance data

In comparison with other sites, Malikas (Site 2) recorded the highest number of endemic species. Several factors threaten the endemic anuran species, such as habitat disturbance, leading to a smaller distribution range (e.g., Le et al. 2020; Carrasco et al. 2021; Faggioni et al. 2021; Liu et al. 2021). Meanwhile, according to personal communication with the residents in the area, Mt. Gutom was previously logged between the 1960s and 1970s. Some machinery for logging activities is still in the area, including the road for trucks transporting the logs, which were also visible. This activity leads to habitat change and fragmentation, which is the primary cause of biodiversity loss worldwide (Tan et al. 2023) and contributes to a decrease in species' potential distribution (Mayani-Parás et al. 2019). According to numerous studies (Berenguer et al. 2021; Bodo et al. 2021; Hamel 2024; Maurya and Vivek 2025), large-scale tree cutting can lead to deforestation, resulting in fragmented habitats for animals. This is especially true for anurans, as they generally have smaller home ranges (Torralvo et al. 2022; Flores et al. 2024b), thus significantly impacted by signs of habitat alteration and destruction, leading to displacement (Cushman 2006). Additionally, according to Wells (2010), the presence and abundance of different frog species can be attributed to various environmental factors that play a crucial role in their survival.

The analysis of anuran assemblages across different sites reveals clear patterns that highlight the ecological variation within the Mt. Gutom Protected Landscape. According to the Bray-Curtis similarity index (Figure 4) the Lower Gutom and Upper Gutom (Cluster 2) support highly similar overlapping communities (approximately 75%), suggesting that these sites function as a relatively continuous habitat, likely maintaining comparable environmental conditions that favor a similar composition and relative abundance of species. Some notable features of the two study sites include the presence of water bodies, continuous riparian zones, comparable forest structures, and the minimal barriers in the area allowing species dispersal (Godinho and Da Silva 2018; Tonkin et al. 2018; Rais and Ahmed 2021). The tight clustering of these areas may imply that they provide consistent breeding sites, calling habitats, as well as suitable microhabitats for the different species, such as the understory vegetation, leaf litter and small streams, which are crucial for the survival of numerous species of anurans with specific moisture and breeding requirements (González-del-Pliego et al. 2020). Apart from this, the similarity of species assemblage can also be influenced by altitudinal gradients, shaping temperature, vegetation type, and humidity (Carvalho-Rocha et al. 2021).

In contrast, the lower similarity between Malikas and Sikitan (Cluster 1) indicates more distinct assemblages despite being grouped relative to the other sites. This suggests that while they may share broad habitat types (such as forested areas), local variation such as canopy cover percentage, present of intermittent streams (de Oliveira and Eterovick 2009) or the variation in ground cover could be creating unique habitats (Ramalho et al. 2022) and specialized niches (Evans 2019; Graziano et al. 2022; Hending et al. 2023). According to Torralvo et al. (2022), greater habitat heterogeneity can support different species, leading to differences in the species assemblage and relative abundances by providing diverse ecological niches. Apart from this, natural landscape features such as ridges, dry patches, or varying degrees of forest openness could limit the movement of some species, reducing overlapping pools even on short distances (Safar et al. 2022). Sites with more edge-like characteristics may favor species that tolerate drier or more open conditions, while sites with denser forest cover may support moisture-dependent or forest specialist frogs (Granda-Rodriguez et al. 2025). This is also noted with other studies conducted around the Philippines, which found that minimally disturbed secondary forests host distinct assemblages compared to more degraded lowland sites (Aureo and Bande 2019; Decena et al. 2020; Solania et al. 2021).

With this, the patterns of the anuran assemblage underline that the species distribution in Mt. Gutom is strongly shaped by local-scale environmental variation. Therefore, understanding these clusters helps identify priority areas for site-specific management. Cluster 2 sites may benefit most from strategies that maintain or restore continuous aquatic habitats and riparian buffers to support the breeding and larval development. Meanwhile, conservation strategies in Cluster 1 might prioritize preserving habitat mosaics and ensuring connectivity between patches to maintain species exchange and genetic flow. By recognizing how natural habitat factors drive these patterns, conservation efforts can better match the ecological requirements of the local anuran communities, helping sustain both species richness and functional diversity across the landscape.

Moreover, the results of SIMPER analyses (Table 3) showed that nine species of anurans (*L. leytensis, L. magnus, P. leucomystax, R. pardalis, A. mcgregori, K. sinensis, L. lumadorum, S. natator,* and *A. muelleri*) were the major contributors to the observed variations between the sampling sites in Sikitan (site 1), Lower/Upper Gutom (sites 3 and 4). The average dissimilarity between these sites was 33.87% with the primary contributors being *L. leytensis* (10.44%), *L. magnus* (9.67%), *P. leucomystax* (9.48%), and *R. pardalis* (9.48%). The relatively moderate dissimilarity suggests a somewhat overlapping assemblage, although with notable differences in species abundance. Apart from this, it was shown that the Dissimilarity/SD values for some species, particularly *P. leucomystax* and *R. pardalis* (27.59%), indicate relatively high consistency in their contributions to dissimilarity across samples.

In contrast, the comparison between Malikas (Site 2) and Lower/Upper Gutom (sites 3 and 4) yielded a substantially higher average dissimilarity of 51.81%, highlighting a more distinct community composition at Malikas. At least 10 species of anurans, including *L. magnus, P. worcesteri, P. surdus, L. lumadorum, O. laevis, L. bimaculatus, L. parvus, P. brevipes, C. fusca*, and *P. acutirostris*, were identified as key contributors. Among them, *L. magnus* (16.66%), *P. worcesteri* (8.99%), *P. surdus* (8.28%), and *L. lumadorum* (7.52%) stood out as the top contributors. These species also showed high Dissimilarity/SD values, indicating a consistently strong influence across replicates. This underscores a clear ecological distinction between Malikas and the other sites.

Table 3. SIMPER (Similarity Percentage) analysis showing the relative contributions of anuran species to the observed dissimilarities in species composition between sampling sites in Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines. Average dissimilarity, ratio of Dissimilarity to Standard Deviation (Diss/SD), percentage contribution of each species to overall dissimilarity, and cumulative contributions (%) are presented for two comparisons

	Ave. dissimilarity	Dissimilarity/SD	Contribution (%)	Cumulative (%)
Sikitan vs. Lower Gutom/Upper Gutom (Ave. Dissimilarity:33.87%)				
Limnonectes leytensis	3.54	1.32	10.44	10.44
Limnonectes magnus	3.28	9.38	9.67	20.11
Polypedates leucomystax	3.21	27.59	9.48	29.59
Rhacophorus pardalis	3.21	27.59	9.48	39.08
Ansonia mcgregori	2.69	10.96	7.95	47.03
Kalophrynus sinensis	2.37	0.71	6.99	54.02
Leptobrachium lumadorum	2.13	27.59	6.3	60.32
Staurois natator	2.03	4.13	6.01	66.32
Ansonia muelleri	1.82	20.89	5.38	71.71
Malikas vs. Lower Gutom/Upper Gutom (Ave. Dissimilarity:51.81%)				
Limnonectes magnus	8.63	16.37	16.66	16.66
Philautus worcesteri	4.66	28.42	8.99	25.65
Philautus surdus	4.29	1.99	8.28	33.93
Leptobrachium lumadorum	3.9	28.42	7.52	41.45
Occidozyga laevis	3.03	5.42	5.85	47.30
Rhacophorus bimaculatus	3.03	5.42	5.85	53.15
Limnonectes parvus	3.00	2.12	5.78	58.93
Pelophryne brevipes	2.72	28.42	5.24	64.17
Chaperina fusca	2.72	28.42	5.24	69.41
Philautus acutirostris	2.72	28.42	5.24	74.65

Overall, the SIMPER analysis indicates that anuran communities differ more markedly between Malikas and the Lower/Upper Gutom sites than between Sikitan and the same sites. These differences are largely driven by changes in the abundance and presence of certain species such as *L. lumadorum*, *L. magnus*, and several *Philautus* spp., which may reflect variations in microhabitat structure, elevation, or other localized environmental gradients (Barria et al. 2020). These findings support the earlier Bray-Curtis results and suggest that while some overlap exists, Malikas harbors a particularly distinct anuran assemblage. This distinctiveness points to the potential ecological uniqueness of Malikas, possibly due to site-specific environmental conditions or microhabitats that support specialized species. Thus, Malikas may require site-specific protection measures, such as microhabitat-level management or localized conservation zoning, to effectively preserve its unique amphibian community. This is particularly important given that some species in the area exhibit narrow habitat preferences or limited dispersal capabilities (Flores et al. 2023a, et al. 2024b, c). Tailoring conservation efforts to the specific ecological features of each site will be crucial to ensuring the long-term persistence of anuran diversity on Mt. Gutom. Notably, it also highlights the compositional differences between sites (Malikas and Lower/ Upper Gutom) specifically because of the species *L. lumadorum*, *L. magnus*, and *Philautus* spp. as key contributors. These species are considered habitat specialists with narrow microhabitat requirements being terrestrial, semi-aquatic, and arboreal respectively (Warguez et al. 2013; Coritico et al. 2018; Delima-Baron et al. 2019; Baron et al. 2021), underscoring that even subtle changes in the forest structure can alter community composition.

Diversity indices of anurans

The biodiversity indices (Table 4) across the study sites revealed significant variation in species dominance, diversity, and evenness, offering insights into species distribution patterns and community structure (Figure 5). The Dominance (D) index, which reflects the extent to which a single species dominates a site, was lowest in Malikas (D: 0.1208) and Sikitan (D: 0.1431), suggesting relatively even species distributions and reduced dominance. In contrast, Lower Gutom (D: 0.2535) and Upper Gutom (D: 0.3399) exhibited higher dominance values, indicating that a few species were disproportionately abundant in those sites, specifically the *L. magnus*. High dominance is commonly linked to ecological disturbance or habitat degradation, where competitive exclusion or environmental filtering allows generalist or disturbance-tolerant species to dominate (Krebs 1972; McGill et al. 2007).

The Shannon-Wiener diversity index (H'), further supports this pattern. Malikas recorded the highest diversity (H': 2.328), followed by Sikitan (H': 2.205), both falling within Odum's (1971) "moderate diversity" range (1<H'<3). Meanwhile, Lower Gutom (H': 1.819) and Upper Gutom (H': 1.489) had lower values, indicating low species diversity. Lower H' values are often associated with environmental stressors that reduce niche availability and community stability (Tilman 1999; Kunte 2008). The relatively higher diversity in Malikas may be attributed to its status as a secondary lowland dipterocarp forest with intact riparian features (emerging trees) and minimal topographic variation (flat and gently undulating), which can support diverse microhabitats and niche partitioning. The Evenness index (e^H/S) supports these findings: Malikas (0.79) showed the most even distribution of species, followed by Sikitan (0.70), while Lower Gutom (0.56) and Upper Gutom (0.49) had lower evenness values, reflecting skewed community structures with species dominance. These biodiversity patterns have direct conservation implications. Sites like Malikas and Sikitan, which exhibit relatively high diversity and evenness, may serve as biodiversity refugia and should be prioritized for strict protection or habitat buffering.

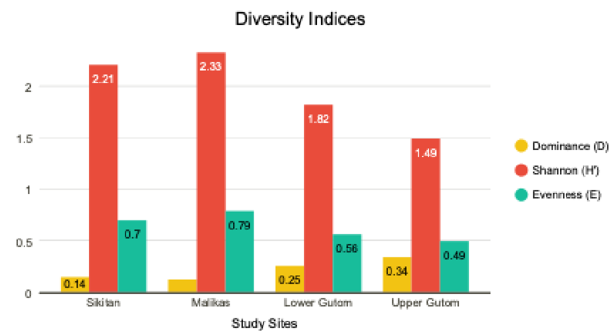

Figure 5. Diversity indices of anuran assemblages from four sampling sites in Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines. Indices include species richness (S), Shannon-Wiener diversity (H′), evenness (e^H/S), and dominance (D), highlighting variation in community structure across Sikitan, Malikas, Lower Gutom, and Upper Gutom

Table 4. Summary of biodiversity indices of anuran assemblage across the four study sites in the Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines. Indices include species richness (S), Shannon-Wiener diversity index (H′), Simpson's diversity index (1-D), Dominance index (D), and Evenness (E = H′/ln S)

Site	Species richness (S)	Shannon (H')	Simpson (1-D)	Dominance (D)	Evenness (E)
Sikitan	13	2.205	0.8569	0.1431	0.70
Malikas	13	2.328	0.8792	0.1208	0.79
Lower Gutom	11	1.819	0.7465	0.2535	0.56
Upper Gutom	9	1.489	0.6601	0.3399	0.49

In contrast, the lower diversity and higher dominance observed at Lower and Upper Gutom suggest these areas may be experiencing ecological degradation. Therefore, they could benefit from restoration efforts such as reforestation, water quality management, or invasive species control to restore community balance and support recolonization by sensitive species. Understanding these patterns allows conservation managers to make informed decisions: protecting high-integrity habitats while also identifying degraded sites where targeted habitat restoration could enhance anuran diversity and ecosystem resilience. Overall, these diversity patterns suggest that Malikas and Sikitan may harbor the most stable and diverse anuran assemblage as compared to other sites, while Lower and Upper Gutom reflect conditions that may favor the ecological dominance and reduced species diversity, probably because of the habitat differences and environmental disturbance.

The Mt. Gutom Protected Landscape has long been subjected to anthropogenic pressures such as poaching, illegal logging, agricultural expansion, and forest clearing for human settlements. These anthropogenic activities are known drivers of habitat degradation and biodiversity loss, particularly for anurans that rely on specific microhabitats. This study presents the first systematic assessment of anuran diversity in Mt. Gutom Protected Landscape, confirming its status as an important refuge of anurans within Mindanao's remaining forests. The notable high proportion of endemic species, including the abundance of the Near Threatened *L. magnus,* confirms Mt. Gutom's role as a refuge for species that are vulnerable to habitat loss (Sanguila et al. 2016; Carrasco et al. 2021). As amphibians have limited dispersal abilities and small home ranges (Cushman 2006; Torralvo et al. 2022), anthropogenic disturbances and habitat fragmentation threaten their survival. Most especially, this mountain area supports numerous species as compared to other mountains around Mindanao.

So, this study confirms that Mt. Gutom Protected Landscape supports diverse and ecologically important anuran species, especially those that are considered as near threatened (*L. magnus*), endemic in the Philippines (*L. leytensis, P. surdus, S. natator*) and in Mindanao as well (*A. mcgregori, A. muelleri, P. brevipes, L. magnus, L. parvus, L. lumadorum, P. stejnegeri, K. sinensis, L. bimaculatus, P. acutirostris, P. worcesteri, P. grandocula*). The distinct patterns of species richness, assemblage similarities, and diversity indices show that habitat heterogeneity, stream integrity, and minimal disturbance strongly shape anuran communities. Apart from this, the findings from this study align with the other papers conducted in Mindanao Mountains, reinforcing Mt. Gutom's regional conservation significance. Therefore, this study recommends taking immediate action in the area to protect critical microhabitats as well as restore degraded sites to ensure the long-term survival of these susceptible organisms. So, targeted conservation and restoration are important specifically in maintaining riparian buffers and stream integrity, supporting and sustaining the breeding habitats of the rheophilic species. Meanwhile, preserving forest heterogeneity and canopy connectivity can protect the direct developing species that rely on leaf litter and arboreal niches. Apart from this, restoring riparian buffers and maintaining continuous forest cover will also help enhance the habitat quality of anurans. Engaging local communities for conservation, habitat rehabilitation and establishing a long-term monitoring plot for tracking population trends and habitat changes. Lastly, this study recommends strengthening local enforcement against illegal logging and habitat changes (which is visible in the area) to ensure compliance with national protected area policies.

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