

Trail-Based Occurrence, Abundance, and Distribution of *Lindsaea hamiguitanensis* (Lindsaeaceae) in the Core Zone of Mt. Hamiguitan Range Wildlife Sanctuary, Eastern Mindanao, Philippines

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ABSTRACT

Baseline data are needed to support conservation monitoring of narrow endemic ferns in protected mountain ecosystems. This study documented the trail-based occurrence, abundance, colony distribution, and mapped distribution of *Lindsaea hamiguitanensis* in the core zone of Mt. Hamiguitan Range Wildlife Sanctuary, Eastern Mindanao, Philippines. A non-destructive opportunistic survey was conducted along five accessible segments of the San Isidro Trail from 28 March to 1 April 2024 using GPS recording, photography, and descriptive abundance summaries. The survey recorded 3,412 mature individuals, 105 field-observed colonies, and 162 GPS occurrence points. Mature individuals were highest in the 901–1050 m mossy forest band, whereas colonies were highest in the 1051–1300 m mossy-pygmy forest band. Findings provide baseline information for conservation monitoring and trail management.

INTRODUCTION

Ferns and lycophytes are important components of tropical and montane forest understories because they contribute to understory structure, organic-matter accumulation, soil stabilization, rhizosphere interactions, and habitat heterogeneity (Nowicki, 2017; Sharpe et al., 2010). Their ecological relevance extends beyond species richness because fern-dominated understories may influence soil processes and carbon storage during forest recovery (Cicuzza & Mammides, 2022; Lyu et al., 2019), while fern physiology is closely linked to water relations, light exposure, temperature, and reproductive life-stage sensitivity (Anderson, 2021; Lyu et al., 2019; Sharpe et al., 2010).

Studies on fern communities show that soil properties, topography, forest structure, elevation, moisture, canopy condition, and microclimate can influence fern abundance, richness, and composition across tropical and subtropical landscapes (Cicuzza & Mammides, 2022; Watkins et al., 2006; Zu et al., 2024). These relationships are especially relevant in mountain ecosystems, where changes in elevation often coincide with shifts in humidity, cloud exposure, substrate availability, and forest physiognomy (Ramos et al., 2026; Watkins et al., 2006).

In the Philippines, Mindanao supports substantial pteridophyte diversity, including threatened and endemic lycophytes and ferns, field-based studies in Mindanao protected areas emphasize that local distribution records remain important because many threatened species have incomplete or unevenly documented ranges (Amoroso et al., 2016; Coritico & Amoroso, 2020; Silverio et al., 2021). For conservation-sensitive taxa, site-level occurrence and abundance records are needed not only for floristic documentation but also for monitoring, ecotourism regulation, and habitat management, especially in fragile and protected areas (Agduma et al., 2023; Dalton et al., 2024; Lovegrove, 2016; Mallari et al., 2016).

Lindsaea hamiguitanensis D.N.Karger & V.B.Amoroso is a Philippine endemic fern originally described from Mt. Hamiguitan, Davao Oriental (Karger et al., 2012), with subsequent records from Mt. Sinaka, Arakan, North Cotabato (Silverio et al., 2021), and Negros Island (Pelser et al., 2011 onwards). The species has been recognized in Mindanao fern conservation literature as a threatened endemic taxon and is listed as Vulnerable in the Updated National List of Threatened Philippine Plants and Their Categories (Coritico & Amoroso, 2020; Silverio et al., 2021; DENR Administrative Order No. 2026-20, 2026). Because colonies occurring along accessible trails may be vulnerable to trampling, incidental damage, habitat disturbance, and unregulated visitation (Agduma et al., 2023), evidence-based baseline information on its occurrence, abundance, and habitat distribution is essential for conservation planning, trail management, visitor-impact assessment, and long-term monitoring (Barros Andrade et al., 2026; Coritico & Amoroso, 2020; Dalton et al., 2024; Nowicki, 2017). Although previous floristic and conservation studies have confirmed the taxonomic and conservation importance of *L. hamiguitanensis*, available information remains insufficient for site-level monitoring within trail-accessible portions of MHRWS. In particular, current literature does not provide a dedicated baseline on its

observed abundance, colony occurrence, and elevational distribution along protected-area trails. Addressing this gap is important because trail-accessible populations may be exposed to trampling, incidental damage, and visitor-related disturbance.

Located in Davao Oriental, Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) is a protected mountain landscape recognized as Mindanao's only UNESCO World Heritage Site and an ASEAN Heritage Park, with distinct forest formations and high native plant diversity (Amoroso et al., 2016; Amoroso & Aspiras, 2011). Its dipterocarp, montane, mossy, and mossy-pygmy forest zones provide contrasting substrates and microclimatic conditions, including shaded understories, moss-covered surfaces, decayed wood, organic litter, and humid forest-floor environments (Amoroso & Aspiras, 2011). Recent work on MHRWS further emphasizes that elevation is associated with shifts in species diversity, endemism, and vegetation structure, reinforcing the need to document species-level patterns across elevation bands (Ramos et al., 2026).



Figure 1. *Lindsaea hamiguitanensis* D.N.Karger & V.B.Amoroso photographed in situ along the San Isidro Trail, Mt. Hamiguitan Range Wildlife Sanctuary. Photos by L.B. Bation.

Despite the taxonomic recognition and conservation significance of *Lindsaea hamiguitanensis*, site-level information on its trail-based occurrence, abundance, colony distribution, and spatial distribution within the core zone of Mount Hamiguitan Range Wildlife Sanctuary remains limited. Existing studies have established the species' taxonomic identity, conservation relevance, and occurrence in selected Philippine localities; however, a dedicated field-based baseline documenting its distribution along protected-area trails has not yet been adequately developed. This information gap is important because populations occurring near or along established trails may be exposed to localized anthropogenic pressures, including trampling, trail widening, incidental disturbance, and visitor-related impacts. Generating such baseline information is therefore necessary to identify priority monitoring areas, guide low-impact trail

management, and support conservation planning for this narrow endemic and nationally Vulnerable fern.

The present study provides a localized, non-destructive, and GPS-supported assessment of visible mature individuals, field-observed colonies, and the generalized trail-based distribution of *L. hamiguitanensis* along the San Isidro Trail. By documenting the species across elevation bands and forest types, the study contributes to fern conservation, protected-area management, and site-level biodiversity monitoring in Mount Hamiguitan Range Wildlife Sanctuary. Specifically, this study aimed to: (1) document the abundance of visible mature individuals and field-observed colonies of *L. hamiguitanensis* across sampled elevation bands and forest types; (2) present its generalized mapped trail-based distribution along the San Isidro Trail; and (3) identify conservation implications relevant to repeated monitoring, visitor guidance, and low-impact trail management.

THEORETICAL REVIEW

Endemic Fern Conservation in Tropical Mountain Ecosystems

Ferns and lycophytes are important components of tropical forest understories because they contribute to habitat complexity, organic-matter retention, soil protection, nutrient cycling, and microhabitat stability (Deng et al., 2023; Sharpe et al., 2010). Their persistence is strongly influenced by environmental conditions because their life cycle includes sporophyte, spore, and gametophyte stages, with the gametophyte stage being especially sensitive to desiccation, excessive light, and unstable substrates (Anderson, 2021; Krieg & Chambers, 2022). These ecological characteristics help explain why many fern species are associated with shaded, humid, and substrate-stable forest environments. Fern endemism is a major conservation concern in tropical mountain ecosystems because restricted-range species are often associated with specialized habitat conditions and limited known occurrence records (Barros Andrade et al., 2026; Wang et al., 2016). In Mindanao, several studies have documented threatened and endemic ferns and lycophytes in protected areas, but many taxa still require field-based validation of their distribution, abundance, and habitat associations (Amoroso et al., 2016, 2019; Coritico & Amoroso, 2020; Silverio et al., 2021). For narrow endemic species, localized occurrence and abundance data are necessary to support monitoring, conservation planning, and site-level management.

Mt. Hamiguitan as Habitat for *Lindsaea hamiguitanensis*

Mt. Hamiguitan Range Wildlife Sanctuary is a biologically significant mountain landscape in southern Mindanao, recognized for its native flora, distinctive vegetation zones, and high conservation value (Amoroso & Aspiras, 2011). Its elevational sequence of dipterocarp, montane, mossy, and mossy-pygmy forests provides varied combinations of humidity, light, substrate, canopy cover, organic matter, and moss cover that can support diverse understory plant communities (Amoroso et al., 2016; Ramos et al., 2026). Floristic and fern-focused studies have established Mt. Hamiguitan as an important center of plant diversity and fern endemism. Earlier assessments recorded 878 plant

species, including 41 ferns and 14 fern allies, while later fern inventory documented 152 species of ferns and lycophytes representing 72 genera and 27 families (Amoroso et al., 2009, 2016). These studies also recorded Philippine endemic and threatened fern species, including *Lindsaea hamiguitanensis*, a species originally described from Mt. Hamiguitan and associated with lower montane rainforest habitats at approximately 1100–1200 m elevation (Amoroso et al., 2016; Karger et al., 2012).

Elevational and Microhabitat Basis for the Study

Elevation is an important ecological factor in fern distribution because it is associated with changes in temperature, humidity, rainfall, cloud exposure, light availability, slope, soil development, and vegetation structure (de Villa & Lagat, 2024; Ramos et al., 2026; Watkins et al., 2006). Studies on fern communities show that species richness, abundance, and composition may vary across elevational gradients due to these interacting environmental conditions (Watkins et al., 2006; Zu et al., 2024). Microhabitat conditions further influence fern occurrence within elevation zones. Soil characteristics, forest structure, topography, canopy condition, light availability, substrate stability, and moisture can affect the establishment and persistence of fern populations (Cicuzza & Mammides, 2022; Deng et al., 2023). For *L. hamiguitanensis*, these factors are especially relevant because the species was observed along forested trail environments where shaded conditions, high humidity, moss cover, decayed wood, organic matter, riverbanks, and rocky substrates may influence local occurrence and abundance.

Need for Baseline Monitoring

Conservation baselines provide reference information for evaluating present conditions and detecting future ecological change. In protected areas, baseline monitoring should generate management-relevant information on species occurrence, abundance, habitat condition, and threats (Dalton et al., 2024; Gillson et al., 2011). For narrow-range and threatened species, such information helps identify priority areas for monitoring, visitor-impact control, and habitat protection. Although previous studies have established the taxonomic identity and conservation importance of *L. hamiguitanensis*, available literature remains limited in terms of its localized trail-based occurrence, abundance, and elevational distribution within the Mt. Hamiguitan Range Wildlife Sanctuary core zone. This gap limits the ability of protected-area managers and researchers to assess present conditions, monitor future changes, and design site-specific conservation actions. Therefore, the present study provides a descriptive baseline by documenting the visible mature individuals, colony occurrence, and elevational distribution of *L. hamiguitanensis* along the San Isidro Trail.

METHODOLOGY

Study Area

The study was conducted in the core zone of Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) in Davao Oriental, southern Mindanao,

Philippines (Figure 2). MHRWS is a protected mountain landscape characterized by elevationally structured vegetation and habitat heterogeneity, making it an important site for biodiversity research and conservation.

Field sampling was undertaken along the San Isidro Trail, a route that traverses a range of forest formations and environmental conditions from lower to higher elevations. The survey area was divided into five elevation bands: 450-600 m, 601-750 m, 751-900 m, 901-1050 m, and 1051-1300 m. The elevation bands were used as descriptive categories for summarizing field observations and should not be interpreted as statistically replicated sampling strata because the survey followed an accessible trail route rather than a fully randomized sampling design. These elevation bands corresponded to distinct forest types and associated microhabitat conditions documented along the trail, including dipterocarp forest, montane forest, montane-to-mossy forest, mossy forest, and mossy-pygmy forest microhabitats across these bands included features such as decayed logs, tree bark, leaf litter, river banks, tributaries, rocky areas, low-light and high-humidity conditions, rich organic matter, stable temperature, and abundant moss cover (Figure 3). Because trail length and total searched area were not measured, the abundance values reported in this study represent observed trail-based counts and are not presented as density estimates, population-size estimates, or complete population counts for the entire MHRWS core zone.

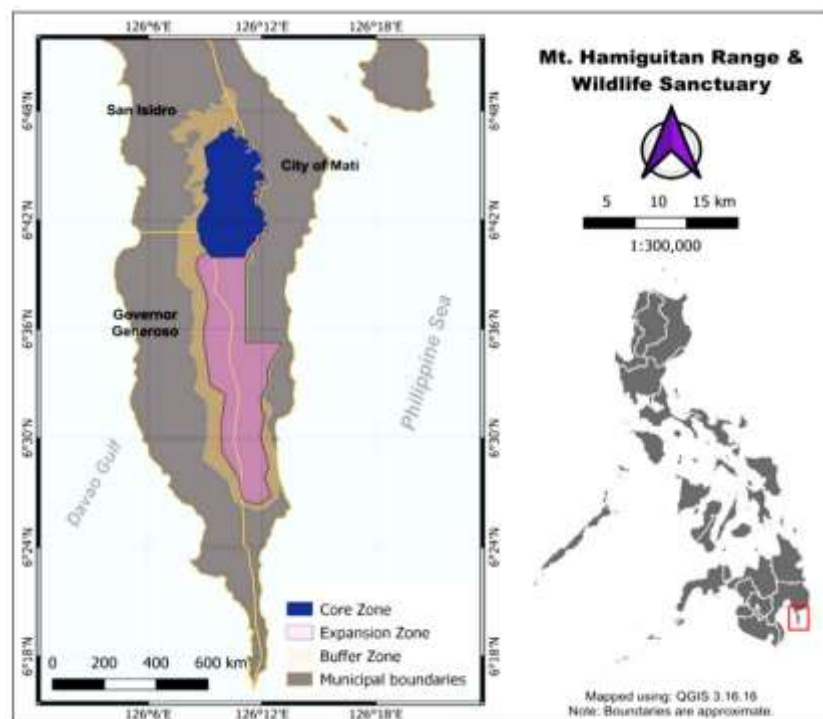


Figure 2. Location map of Mt. Hamiguitan Range Wildlife Sanctuary showing the core, buffer, and expansion zones.

Site	Elevation band	Forest type	Recorded microhabitat
5	1051-1300 m	Mossy-pygmy forest	Abundant mosses; high humidity; shaded conditions
4	901-1050 m	Mossy forest	High humidity; low-light conditions; rich organic matter; stable temperature
3	751-900 m	Montane to mossy forest	Low-light conditions; high humidity; river banks
2	601-750 m	Montane forest	River banks and tributaries; rocky areas
1	450-600 m	Dipterocarp forest	Decayed trees and logs; tree bark; leaf litter

Figure 3. Elevational survey sites, forest types, and recorded microhabitats across five elevation bands.

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Research Design and Field Survey

Field observations were conducted from 28 March to 1 April 2024 using a non-destructive, trail-based opportunistic survey design. The San Isidro Trail was surveyed once by eight observers. The survey covered five accessible trail segments corresponding to the five elevation bands: 450–600 m, 601–750 m, 751–900 m, 901–1050 m, and 1051–1300 m. Each accessible trail segment within an elevation band was searched for approximately 5–10 minutes, with a maximum search width of 10 m, extending approximately 5 m on either side of the trail. The survey prioritized visible individuals and colonies encountered along accessible trail sections, with observations recorded using GPS and mobile-phone photography. Because the design was opportunistic and constrained by trail accessibility and safety conditions, the results are interpreted as baseline occurrence and abundance records rather than standardized estimates of population density. Other access routes, including the Governor Generoso–Camp III trail, the alternate route from the peak to Camp IV, and the Tinagong Dagat–Hidden Garden trail, were not surveyed because access was restricted following shearline- and low-pressure-area-related flooding and landslides in January and February 2024 (Patumbon, 2024). These events affected portions of the MHRWS trail system associated with streams and river networks, limiting safe access to several survey routes. Each accessible trail segment was searched

for approximately five minutes within a maximum search width of 10 m, extending about 5 m on either side of the trail. The assessment was authorized through MHRWS-PAMB Resolution No. 37, Series of 2023. Exact public reporting of coordinates is restricted because *L. hamiguitanensis* is conservation-sensitive and nationally listed as Vulnerable.

Occurrence and Abundance Recording

Visible mature individuals and fern colonies were counted and documented using GPS and mobile-phone photography. A total of 162 GPS occurrence points was recorded during the survey. For this study, a visible mature individual was operationally defined as a field-recognized *L. hamiguitanensis* plant with fully developed fronds and morphology consistent with adult plants observed during the survey. Juvenile or uncertain individuals were not separately analyzed. Because the survey was non-destructive, belowground rhizome connections were not examined; therefore, counts refer to visible mature aboveground individuals rather than genetically distinct individuals. A colony was operationally defined as a spatially clustered group of visible *L. hamiguitanensis* individuals occurring in close proximity on the same local substrate or microhabitat patch. For observer consistency, colonies were treated as field-observed clusters rather than confirmed clonal units.

To reduce duplicate counting of clustered plants, four observers searched each side of the trail simultaneously and coordinated counts across the trail width. Field counts were checked among observers during the survey to ensure that visible mature individuals and colonies were recorded consistently. Four Garmin GPSMAP 65s multi-band GPS handheld units with sensors were used to record occurrence locations. To protect the species from disturbance or unauthorized collection, exact coordinates were excluded from the public manuscript and only generalized distribution information was presented.

Species identification was based on the diagnostic description of *L. hamiguitanensis* provided in the original species description and related taxonomic references (Karger et al., 2012). Field identification was further supported by photographic comparison with confirmed reference images and records available from Co's Digital Flora of the Philippines database (Pelser et al., 2011). Photographs of observed individuals were checked against these reference materials to verify field identification.

Gis Mapping and Data Analysis

GPS coordinates were imported and analyzed in ArcMap 10.3 and overlaid with a Digital Elevation Model (DEM) layer sourced from WorldClim (<https://www.worldclim.org/data/bioclim.html>) to map the observed distribution of the species across the sampled elevation bands (Fick & Hijmans, 2017). The distribution map was used to visualize trail-accessible occurrences of *L. hamiguitanensis* within the surveyed core-zone trail. Data were summarized descriptively by site, elevation band, forest type, mature fern count, fern-colony count, and relative abundance. Relative abundance was calculated as the number of mature individuals recorded in a site divided by the total number of mature individuals recorded across all sites, multiplied by 100. Inferential statistical

comparisons were not retained because the independent sampling unit, number of observations per elevation category, and treatment of aggregated field observations were not sufficiently documented for robust hypothesis testing.

RESULTS

Occurrence and Abundance Across Elevation Bands

The trail-based survey recorded 3,412 visible mature individuals and 105 fern colonies of *Lindsaea hamiguitanensis* across the five surveyed elevation bands (Table 1). Mature individuals were recorded in all elevation bands, from 450–600 m to 1051–1300 m, although their abundance varied markedly among forest types and microhabitat conditions.

The highest number of visible mature individuals was recorded in the 901–1050 m mossy forest band, with 2,610 individuals, representing 76.49% of the total count. This was followed by the 1051–1300 m mossy-pygmy forest band, with 465 individuals or 13.63%, and the 751–900 m montane-to-mossy forest band, with 150 individuals or 4.40%. Lower counts were recorded in the 601–750 m montane forest band, with 116 individuals or 3.40%, and the 450–600 m dipterocarp forest band, with 71 individuals or 2.08%. These results indicate that mature individuals were most concentrated in the upper-elevation mossy forest zone, particularly in humid, shaded habitats with rich organic matter and relatively stable temperature conditions.

Colony counts showed a slightly different pattern from mature-individual abundance. The highest number of colonies was recorded in the 1051–1300 m mossy-pygmy forest band, with 34 colonies, despite having fewer mature individuals than the 901–1050 m band. The 601–750 m montane forest and 901–1050 m mossy forest bands each recorded 27 colonies, while the 751–900 m montane-to-mossy forest band recorded 17 colonies. No fern colonies were recorded in the 450–600 m dipterocarp forest band, although 71 visible mature individuals were observed in this elevation range. In general, *L. hamiguitanensis* was most abundant in the 901–1050 m mossy forest band, while colony occurrence was highest in the 1051–1300 m mossy-pygmy forest band.

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montane-to-mossy forest band recorded 17 colonies. No fern colonies were recorded in the 450–600 m dipterocarp forest band, although 71 visible mature individuals were observed in this elevation range.

Table 1. Trail-based mature-individual counts, colony counts, relative abundance, forest type, and microhabitat characteristics of *Lindsaea hamiguitanensis* across elevation bands along the San Isidro Trail, Mt. Hamiguitan Range Wildlife Sanctuary.

Site	Elevation (m)	No. of Mature Ferns (n)	Total Fern Colonies	Relative Abundance (%)	Forest Type	Microhabitat
1	450-600	71	0	2.08	Dipterocarp forest	Decayed trees and logs, tree bark, leaf litter
2	601-750	116	27	3.40	Montane forest	Riverbanks, tributaries, and rocky areas
3	751-900	150	17	4.40	Montane to mossy forest	Low-light conditions, high humidity, and riverbanks
4	901-1050	2,610	27	76.49	Mossy forest	High humidity, low-light conditions, rich organic matter, and stable temperature
5	1051-1300	465	34	13.63	Mossy-pygmy forest	Abundant mosses, high humidity, and shaded conditions

In general, *L. hamiguitanensis* was most abundant in the 901–1050 m mossy forest band, while colony occurrence was highest in the 1051–1300 m mossy-pygmy forest band. The observed distribution suggests that humid, shaded, upper-elevation habitats, particularly mossy and mossy-pygmy forest environments (Ramos et al., 2026; Zu et al., 2024), may provide favorable microhabitat conditions for the persistence of the species along the surveyed trail.

Trail-Based Distribution

The georeferenced distribution map showed that recorded occurrences followed the surveyed trail gradient from lower-elevation forest toward mossy and mossy-pygmy zones (Figure 4). The distribution output provides a spatial baseline for trail-accessible observations. Exact coordinates were withheld in the article because the species is conservation-sensitive and nationally listed as Vulnerable.

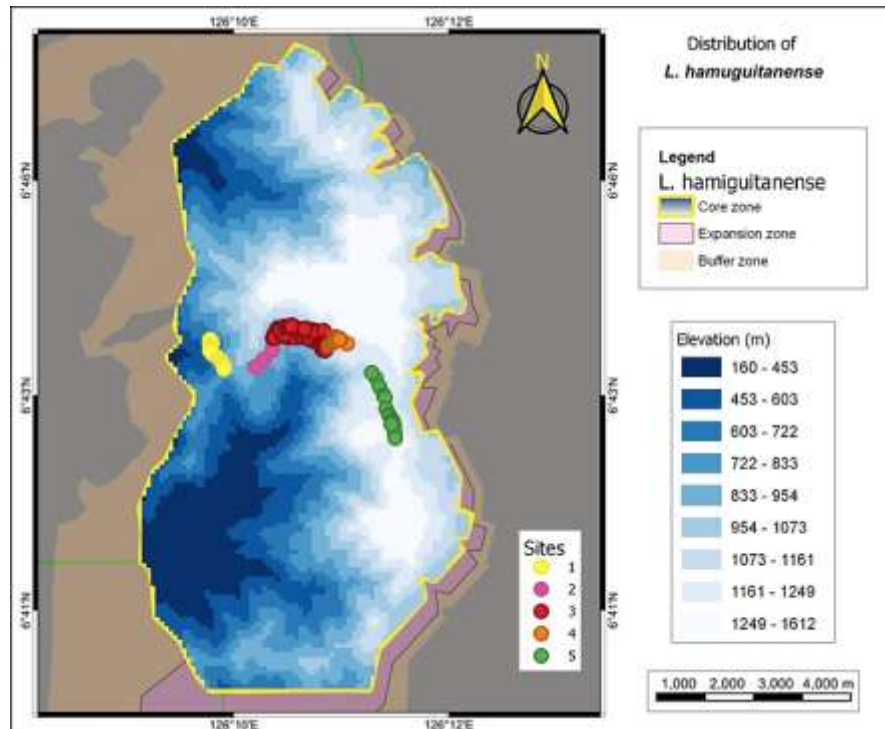


Figure 4. Generalized trail-based distribution map of *Lindsaea hamiguitanensis* across five elevation bands in the MHRWS core zone. Exact occurrence coordinates are withheld for conservation sensitivity because the species is nationally listed as Vulnerable.

DISCUSSION

This study provides a descriptive, trail-based baseline for the occurrence, abundance, colony distribution, and mapped distribution of *L. hamiguitanensis* along the San Isidro Trail in the core zone of MHRWS. The survey documented 3,412 visible mature individuals, 105 field-observed colonies, and 162 GPS occurrence points across five accessible trail segments representing five elevation bands and associated forest types. Because the survey was opportunistic, non-destructive, and limited to accessible trail sections, the results should not be interpreted as estimates of population density, total population size, or complete distribution within the protected area. Rather, they provide field-based occurrence and abundance records useful for protected-area monitoring and trail-management planning.

The strongest pattern observed was the concentration of visible mature individuals in the 901–1050 m mossy forest band, where 2,610 individuals, equivalent to 76.49% of the total count, were recorded. This was followed by the 1051–1300 m mossy-pygmy forest band, with 465 individuals or 13.63%. Lower counts were recorded in the 751–900 m montane-to-mossy forest, 601–750 m montane forest, and 450–600 m dipterocarp forest bands. This pattern is consistent with studies showing that fern abundance and distribution are influenced by elevation-related changes in moisture, canopy structure, light availability, substrate condition, soil properties, and microclimate (Cicuzza & Mammides, 2022; Watkins et al., 2006; Zu et al., 2024). The high abundance in the mossy forest

band may therefore reflect favorable humid, shaded, organic-rich, and relatively stable microhabitat conditions.

The observed abundance peak in the 901–1050 m band is also consistent with the moisture-sensitive biology of ferns. Fern life cycles include spores and gametophytes that are vulnerable to desiccation, excessive light exposure, and unstable substrates (Anderson, 2021; Krieg & Chambers, 2022). The mossy forest microhabitats recorded in this study, including shaded substrates, rich organic matter, high humidity, and relatively stable temperature, may provide favorable local conditions for the persistence and proliferation of *L. hamiguitanensis*. However, because search effort and surveyed area were not fully standardized across elevation bands, this pattern should be interpreted as a descriptive trail-based observation rather than a statistically tested habitat preference.

The findings also support previous botanical studies recognizing Mt. Hamiguitan as an important center of plant diversity and pteridophyte conservation. Earlier studies documented the high floristic value of MHRWS, including its distinct vegetation zones and diverse fern and lycophyte flora (Amoroso et al., 2016; Amoroso & Aspiras, 2011). *L. hamiguitanensis* was originally described from Mt. Hamiguitan and associated with lower montane rainforest conditions at approximately 1100–1200 m elevation (Karger et al., 2012). In the present study, the highest colony count was recorded in the 1051–1300 m mossy-pygmy forest band, while the highest mature-individual count was recorded in the adjacent 901–1050 m mossy forest band. This suggests that trail-accessible populations may occur across a broader local elevational range than the original type-associated elevation alone would indicate. Nevertheless, this interpretation should remain cautious because the study was not designed to determine the full ecological range or niche limits of the species within MHRWS.

A notable finding was the apparent discrepancy between the elevational patterns of mature-individual abundance and colony occurrence. The 901–1050 m mossy forest band supported the highest number of visible mature individuals, whereas the 1051–1300 m mossy-pygmy forest band had the greatest number of recorded colonies. This pattern suggests that mature-individual counts and colony counts represent different field-based indicators of population structure. Mature-individual counts reflect the number of visible aboveground individuals observed during the survey period, while colony counts represent field-recognized clusters or occupied microhabitat patches (Araki et al., 2009; Tsujimoto et al., 2020). Accordingly, the concentration of mature individuals in the mossy forest band may indicate larger or denser clusters, whereas the greater number of colonies in the mossy-pygmy forest band may reflect more numerous but smaller or more spatially dispersed occupied patches. Because belowground rhizome connectivity was not assessed, the recorded colonies should be interpreted strictly as field-observed clusters rather than genetically distinct clonal units.

The absence of recorded colonies in the 450–600 m dipterocarp forest band, despite the presence of 71 visible mature individuals, warrants critical interpretation. This pattern may indicate that individuals at lower elevations occurred singly or in small, poorly delimited clusters rather than as readily recognizable colonies. One plausible explanation is that the lower dipterocarp

band may provide less continuous suitable microhabitat for colony formation compared with higher mossy or mossy-pygmy habitats. Fern occurrence and richness are commonly associated with shaded and humid microhabitats, and moss cover may influence fern establishment by retaining moisture and modifying local microclimatic conditions (Akomolafe & Rahmad, 2019; Amoroso et al., 2016; Harrington & Watts, 2021). In Mt. Hamiguitan, higher-elevation mossy forest habitats are characterized by abundant mosses, lichens, and epiphytes, whereas dipterocarp forest occurs at lower elevations (Amoroso & Aspiras, 2011; Unep-Wcmc, 2017). Thus, reduced or more discontinuous moss cover, lower moisture retention, or greater variability in understory conditions may have contributed to the occurrence of isolated individuals or poorly defined colonies in the 450–600 m band. However, this interpretation remains inferential because substrate moisture, moss cover, canopy openness, and microclimatic variation were not quantitatively measured. The pattern may also reflect methodological constraints, including the opportunistic trail-based survey design, limited search duration per segment, and difficulty in consistently distinguishing small colonies from isolated individuals. Therefore, the absence of recorded colonies in this band should not be interpreted as evidence that the species does not form colonies at lower elevations. Rather, it highlights the need to refine operational colony definitions and incorporate colony-size or patch-size categories in future monitoring.

The occurrence of *L. hamiguitanensis* across all five elevation bands is also important. Although most individuals and colonies were concentrated in upper-elevation mossy and mossy-pygmy forest habitats, the species was also detected in dipterocarp, montane, and montane-to-mossy forest zones. This suggests that the species should not be described as restricted only to upper-elevation forests based on the present dataset. Instead, suitable microhabitats may occur across several forest types, particularly where shaded, humid, organic-rich, and substrate-stable conditions are present. This interpretation is consistent with studies showing that fern distribution is shaped not by elevation alone but by interacting environmental factors such as moisture availability, canopy condition, substrate type, topography, organic matter, and forest structure (Cicuzza & Mammides, 2022; de Villa & Lagat, 2024; Watkins et al., 2006).

The mapped distribution based on 162 GPS occurrence points provides a spatial baseline for monitoring trail-accessible populations of *L. hamiguitanensis*. Georeferenced biodiversity data are increasingly useful in protected-area monitoring because they help identify priority monitoring areas, assess visitor-related pressures, and support management planning (Barros Andrade et al., 2026; Dalton et al., 2024). In this study, the generalized distribution map identifies elevation bands where repeated monitoring may be prioritized while avoiding public disclosure of exact coordinates. This is appropriate because *L. hamiguitanensis* is nationally listed as Vulnerable and may be vulnerable to disturbance or unauthorized collection if precise locality data are released.

The results have direct implications for trail management in MHRWS. Trail-accessible individuals and colonies may be exposed to trampling, trail widening, incidental damage, and unmanaged visitor movement, particularly in mossy and mossy-pygmy forest environments where substrates are fragile. Studies on

recreational trail impacts have shown that trails can cause vegetation loss, soil disturbance, trail widening, edge effects, and changes in vegetation composition, especially in plant communities of high conservation value (Ballantyne et al., 2016). Previous conservation studies also emphasize that legal protection alone is insufficient without effective monitoring, visitor regulation, and site-specific management interventions (Agduma et al., 2023; Dalton et al., 2024; Mallari et al., 2016). Based on the present findings, the 901–1050 m mossy forest band and the 1051–1300 m mossy-pygmy forest band should be treated as priority zones for repeated non-destructive monitoring and low-impact trail-use management. Overall, this study contributes to the conservation documentation of threatened and endemic ferns in Mindanao by providing a localized, management-oriented baseline for *L. hamiguitanensis* within a trail-accessible portion of its type-locality landscape. Previous studies have emphasized that many Philippine endemic ferns and lycophytes remain incompletely documented and require localized field validation to support conservation planning (Coritico & Amoroso, 2020; Silverio et al., 2021). The present study addresses this need by identifying where visible mature individuals and field-observed colonies are concentrated along a protected-area trail.

CONCLUSIONS AND RECOMMENDATIONS

1. The study documented 3,412 visible mature individuals and 105 field-observed colonies of *Lindsaea hamiguitanensis* along the surveyed San Isidro Trail within the core zone of Mount Hamiguitan Range Wildlife Sanctuary.
2. *Lindsaea hamiguitanensis* was recorded across all five sampled elevation bands, from 450–600 m to 1051–1300 m, indicating that the species occurs across multiple elevation zones and associated forest types along the surveyed trail.
3. The highest number of visible mature individuals was recorded in the 901–1050 m mossy forest band, with 2,610 individuals, representing 76.49% of the total count.
4. The highest number of field-observed colonies was recorded in the 1051–1300 m mossy-pygmy forest band, with 34 colonies. This indicates that colony occurrence and mature-individual abundance did not follow the same distributional pattern.
5. The species was more frequently observed in humid, shaded, and organic-rich microhabitats, particularly in mossy and mossy-pygmy forest environments.
6. The findings provide baseline information for repeated monitoring, trail management, and conservation planning. However, because the study was trail-based and non-standardized, the results should not be interpreted as estimates of total population size, population density, or complete distribution within Mount Hamiguitan Range Wildlife Sanctuary.

Recommendations

1. Install or integrate low-impact conservation reminders in guide briefings and visitor orientation materials, emphasizing that trail users should avoid

stepping on mossy substrates, decayed logs, shaded fern patches, and other microhabitats where *L. hamiguitanensis* may occur.

2. Conduct regular non-destructive monitoring in the 901–1050 m and 1051–1300 m elevation bands because these areas recorded the highest mature-individual and colony counts.
3. Use standardized monitoring methods in future surveys, such as fixed plots, belt transects, repeated sampling, and measured search effort.
4. Record mature individuals and colonies separately because they represent different population indicators.
5. Develop simple colony-size categories, such as small, medium, and large, to improve future monitoring consistency.
6. Strengthen trail management in areas where colonies occur near visitor-accessible paths to reduce trampling, trail widening, and accidental disturbance.
7. Include *L. hamiguitanensis* conservation reminders in guide briefings, visitor orientations, and protected-area education materials.
8. Keep exact GPS coordinates confidential and use only generalized maps in public reports to reduce the risk of disturbance or unauthorized collection.

FURTHER STUDY

Future studies should conduct standardized and repeated population monitoring of *L. hamiguitanensis* using fixed plots, belt transects, or permanent monitoring points. Survey effort, trail length, search area, number of observers, and survey duration should be measured and reported to allow reliable comparisons across elevation bands, forest types, and monitoring periods.

Additional surveys should be carried out along other accessible trails and suitable habitat zones of Mt. Hamiguitan Range Wildlife Sanctuary to determine whether the species occurs beyond the San Isidro Trail and whether the patterns observed in this study reflect broader distribution patterns within the protected area.

Future research should also include quantitative microhabitat measurements, including relative humidity, light intensity, canopy cover, moss cover, substrate type, soil moisture, slope, organic-matter condition, and proximity to streams or riverbanks. These data would help clarify the environmental conditions associated with the occurrence and abundance of *L. hamiguitanensis*.

Repeated seasonal and long-term monitoring is also recommended to assess changes in detectability, reproductive condition, recruitment, colony persistence, and population trends. Future surveys should refine the operational definition of colonies and include colony-size categories to improve the consistency and comparability of monitoring data.

For long-term conservation planning, species distribution mapping or modelling may be developed once sufficient and well-documented occurrence records are available from multiple trails and habitat zones. Occurrence data should be spatially filtered to reduce sampling bias, and environmental predictors should be selected based on ecological relevance and low

multicollinearity. These maps may help identify potential priority habitats, guide future field validation, and support protected-area management planning for this endemic and nationally Vulnerable fern.

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