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Eco-edutourism for biodiversity conservation and community empowerment in Bukit Cubung Karst, Kulon Progo, Indonesia

KUNTUM FEBRIYANTININGRUM[1,2,♥], RAHMANIA PAMUNGKAS[1], AHMAD KAMAL SUDRAJAT[1], MUCHLISA AMALIA ZAHRA[1] , ABRAHAM HUSAIN[1]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta. Jl. Colombo No. 1, Sleman 55281, Yogyakarta, Indonesia. Tel./fax.: +62 274-586168, ♥email: kuntumfebriyantiningrum@uny.ac.id

[2]Doctoral Program in Biology, Faculty of Biology, Universitas Gadjah Mada. Jl. Teknika Selatan, Sleman 55281, Yogyakarta, Indonesia

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Abstract. *Febriyantiningrum K, Pamungkas R, Sudrajat AK, Zahra MA, Husain A. 2026. Eco-edutourism for biodiversity conservation and community empowerment in Bukit Cubung Karst, Kulon Progo, Indonesia. Biodiversitas 27 (6): d270602. https://doi.org/10.13057/biodiv/d270602.* Indonesia's karst landscapes support distinctive biodiversity but remain highly vulnerable to habitat degradation, weak conservation governance, and limited livelihood options for surrounding communities. This study examines how community-based eco-edutourism can link biodiversity conservation and community empowerment in the Bukit Cubung karst area, Kulon Progo, Yogyakarta, using a participatory action research approach. The intervention combined biodiversity inventory (flora and fauna surveys across four microhabitats), ecological literacy training for local participants, and facilitation of community-based tourism governance. Flora sampling across ten 10 m × 10 m plots and transects documented 23 plant species, while fauna surveys recorded 17 non-avian species, yielding Shannon-Wiener diversity values of *H'* = 2.71 for flora and *H'* = 2.43 for fauna, indicating moderately high ecological heterogeneity in the study site. Ecological literacy among 20 community participants increased from a mean pre-test score of 42.1% to 87.8% in the post-test, reflecting substantial improvements in knowledge of local species and karst ecosystem functions. Program implementation supported the formation of a village eco-edutourism committee, the development of simple visitor management rules, and the use of the biodiversity inventory as interpretive material for guiding and environmental education activities. These findings suggest that eco-edutourism, when grounded in site-specific biodiversity data and participatory learning, can strengthen local ecological knowledge, foster shared responsibility for conservation, and contribute to community empowerment in fragile karst landscapes.

Keywords: Biodiversity conservation, community empowerment, eco-edutourism, karst ecosystems

INTRODUCTION

Indonesia, one of the mega-biodiversity countries in the world, is facing unprecedented environmental challenges. Karst ecosystems are among the most distinctive landscapes in the tropics because they combine high geological heterogeneity, specialized habitats, fragile hydrology, and often unique biodiversity. Despite their ecological significance, karst areas across Southeast Asia, including Indonesia, face chronic threats (Wijayanti and Noviani 2020; Arif et al. 2024). Unsustainable land conversion, limestone quarrying, agricultural expansion, and unregulated tourism have resulted in the degradation of karst formations and the loss of associated biota (Angulo et al. 2013; Canedoli et al. 2022). The fragility of karst hydrology, characterized by thin soil layers, high permeability, strong hydrological sensitivity and limited water retention, further exacerbates vulnerability to environmental disturbances (Kaivo-oja et al. 2014; Culver et al. 2019; Canedoli et al. 2022). Consequently, the protection of karst ecosystems requires integrative models that harmonize ecological conservation with community livelihoods (Widodo et al. 2024), knowledge systems (De Waele and Gutiérrez 2022), and local governance structures (Chen et al. 2020).

Bukit Cubung is located in Jatirejo Village, Kapanewon Lendah, Kulon Progo District, forming part of the Gunungsewu Karst System in southern Yogyakarta, Indonesia. The area features limestone outcrops ($CaCO_3$-rich formations), thin soil cover, and seasonal dry streams that recharge local groundwater. Limited documentation of local flora and fauna (Chen et al. 2024a, b, c), weak conservation awareness (Kiss 2004), and the absence of structured ecotourism management have hindered the community's ability to benefit from and sustainably maintain the karst ecosystem (Sulistiyowati et al. 2021; Mičetić Stanković 2023; Kumilamba et al. 2025). While interest in ecotourism within Indonesian karst regions is growing, existing initiatives often prioritize revenue generation over environmental literacy and community stewardship (Goldscheider 2019; Arif et al. 2024).

Prior academic studies largely focus on biophysical elements of karst systems or commercially developed tourism hotspots, with limited attention to participatory models that embed biodiversity knowledge within the visitor experience (Scheyvens 1999; Fennell 2020). Then, there remains a critical gap in empirical research exploring how eco-edutourism can simultaneously strengthen biodiversity protection and community empowerment, particularly in karst regions like Bukit Cubung that are ecologically rich yet understudied and underutilized.

A critical gap exists between ecotourism practice and conservation science, which most models lack integration of rigorous biodiversity data, community-based environmental education, and participatory governance frameworks that simultaneously operationalize global conservation commitments. Additionally, local communities are often treated as service providers or passive beneficiaries rather than co-creators of ecological knowledge and conservation decisions. This gap is particularly acute in rural karst regions of Indonesia, where community agency in biodiversity stewardship remains underdeveloped.

Eco-edutourism, which merges education and ecotourism, has gained recognition as a tool to connect biodiversity conservation with local livelihood improvement (Fennell 2020; Scheyvens 1999). Within this context, the Bukit Cubung Eco-edutourism Program seeks to demonstrate how community-based management and biodiversity documentation can work in synergy to protect karst ecosystems while enhancing economic resilience (Chen et al. 2024a, b, c). Eco-edutourism as an integrative model that merges ecological education with nature-based tourism has emerged globally as a promising mechanism for linking biodiversity conservation with community empowerment. Unlike conventional ecotourism, eco-edutourism foregrounds learning, environmental literacy, and participatory knowledge co-production as central components of visitor experience and local stewardship (Scheyvens 1999; Fennell 2020). When designed collaboratively, eco-edutourism can strengthen conservation-oriented behaviors, diversify livelihood opportunities, and promote community ownership of natural assets. In the context of karst ecosystems, eco-edutourism also provides a platform for translating scientific knowledge about biodiversity, hydrological processes, and endemic species into accessible learning for both local residents and visitors.

Bukit Cubung Eco-edutourism Program was initiated to explore how biodiversity, environmental education, and community-based governance can be integrated to support both ecological and economic resilience. This study examines the implementation of a participatory eco-edutourism model in Bukit Cubung with three specific research objectives: (i) to document flora and fauna biodiversity across four karst microhabitats and calculate diversity indices characterizing ecosystem health; (ii) to assess changes in ecological literacy among participants; (iii) to evaluate how participatory governance structures and institutional development link biodiversity conservation with community empowerment and sustainable livelihoods. By situating local action within global conservation frameworks and Indonesia's national biodiversity strategy, this research contributes empirical evidence and practical methodologies for community-led conservation in fragile karst landscapes.

MATERIALS AND METHODS

Study area

The study was conducted in the Bukit Cubung karst area, Jatirejo Village, Kapanewon Lendah Sub-district, Kulon Progo District, Yogyakarta Special Region, Indonesia (7°54′-7°56′S; 110°13′-110°15′E) (Figure 1). Figure 1 uses a representative location point; therefore, the point shown in Figure 1 indicates the general study site rather than the full spatial boundary of the karst area. The landscape is characterized by limestone outcrops, thin soils, mixed agroforestry, remnant scrub vegetation, and seasonal hydrological features typical of tropical karst environments. Local land use is dominated by smallholder agriculture, agroforestry, and increasing informal tourism activity.

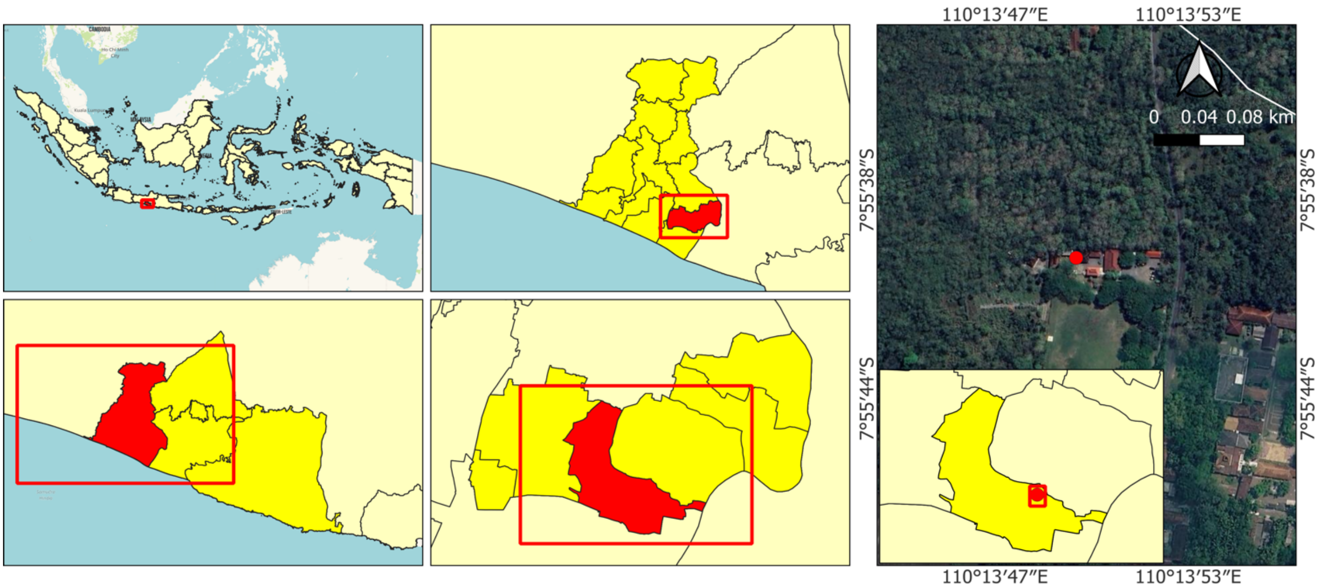

Figure 1. Representative study site of the Bukit Cubung karst area in Jatirejo Village, Kapanewon Lendah, Kulon Progo District, Yogyakarta, Indonesia

Study design

This study used a mixed-methods of participatory action research design that combined biodiversity survey, ecological literacy assessment, and documentation of community-based ecoedutourism activities. The approach emphasized collaborative planning, implementation, observation, and reflection with local stakeholders involved in conservation and tourism activities.

Biodiversity inventory

Ten sample plots (20 m × 20 m) were systematically distributed across differentiated karst microhabitats to capture ecological gradients. This spatial stratification ensures that flora and fauna sampling captures the full range of biodiversity variation typical of karst ecosystems.

Flora sampling

Flora assessment employed standardized plot-based sampling to comprehensively document woody vegetation. Ten sample plots (10 m × 10 m = 100 m² per plot; 0.1 ha total sampling area) were systematically distributed across four karst microhabitats: limestone slope with sparse vegetation (3 plots), cave vicinity with mixed scrub (3 plots), spring zone with riparian vegetation (2 plots), and agroforestry area (2 plots). This spatial distribution ensured representative sampling across habitat gradients. Within each plot, all woody plants with diameter at breast height (DBH) ≥10 cm were identified and counted. Species identification was performed using available field guides for Java flora (Whitmore 1984; Newman et al. 1998). Non-woody flora (shrubs, herbaceous plants, ferns) were documented using walking transect surveys: 10 transects of 100 m length × 2 m width, with all plant species recorded and identified.

Fauna sampling

Fauna were surveyed using taxon-appropriate methods. Birds were surveyed using point counts at 10 observation points for 5 minutes per point during early morning, repeated over 3 field days. Amphibians and reptiles were documented using visual encounter surveys along predetermined transects. Dragonflies were observed at 5 water-source points, and other invertebrates were documented using pitfall traps and visual searches, including spider searches. Because bird detections were limited and insufficient for robust diversity analysis, bird observations were acknowledged as part of survey effort but excluded from fauna diversity-index calculations in the final analysis.

Data analysis

Species inventories for flora (woody plants) and fauna (birds, herpetofauna) were compiled into comprehensive species lists with scientific nomenclature, family assignment, and habitat notes. Biodiversity data for flora and fauna were analyzed using standard community ecology metrics. Species richness (S) was calculated as the total number of species recorded within the sampled plots and transects.

For diversity, we used Shannon-Wiener Diversity index:

$$H' = -\Sigma(pi \times \ln pi)$$

Where, pi: unit of individuals of species i

For dominance, we used Simpson's Dominance index:

$$D = \Sigma(pi^2)$$

For evenness, we used Pielou Evenness index:

$$J = H'/\ln(S),$$

Where, S: number of species

Calculated diversity indices provided baseline characterization of ecosystem health and heterogeneity, informing educational content for biodiversity workshops. Quantitative and qualitative data were obtained from pre-post surveys, focus group discussions, direct observation, supported by qualitative narratives from interviews. Key indicators included knowledge of species diversity, understanding of karst ecosystem functions, and willingness to participate in conservation. Data were analyzed using descriptive statistics.

Eco-edutourism program documentation

Program implementation was documented through observation, focus group discussions, questionnaires, and records of community activities related to biodiversity interpretation, ecoprint production, and governance development. Indicators included participant involvement, use of biodiversity information in learning activities, organizational development, and livelihood outputs associated with eco-edutourism activities.

The eco-edutourism model was implemented through a participatory action research (PAR) approach, conducted by the Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, in collaboration with the village government, Pokdarwis (tourism awareness group), and BUMDes (village-owned enterprise). The activities comprised three main components: (i) Biodiversity Literacy, training on flora and fauna identification using the Book of Biodiversity as an interpretive guide; (ii) Eco-Creative Economy, ecoprint workshops using native plant leaves as pigments, promoting sustainable souvenir production; (iii) Tourism Governance, establishment of community management units, safety and conservation protocols (CHSE), and revenue-sharing mechanisms.

Ecological literacy assessment

Ecological literacy among community participants was assessed using a structured pre-post questionnaire developed specifically for the Bukit Cubung ecoedutourism program. The instrument consisted of 20 multiple-choice and short-answer items covering four domains: (i) identification of local flora and fauna, (ii) understanding of basic karst ecosystem functions (e.g., hydrology, soil characteristics), (iii) awareness of anthropogenic threats to karst biodiversity, and (iv) knowledge of conservation practices and ecoedutourism principles. The questionnaire was administered to the same 20 participants at two time points: immediately before the first biodiversity literacy workshop (pre-test) and after completion of the final workshop (post-test), ensuring that changes in scores reflected the influence of the program.

Each correct answer was scored as one point, and total scores were converted to percentages to facilitate comparison across participants and domains. The questionnaire items were reviewed by three biology education and conservation experts to ensure content validity and alignment with the learning objectives of the ecoedutourism program. This procedure allowed the ecological literacy assessment to function both as a diagnostic tool and as an evaluation of the effectiveness of the biodiversity literacy component of the ecoedutourism intervention.

RESULTS AND DISCUSSION

Environmental gradients in Bukit Cubung Karst area

In Bukit Cubung in Jatirejo Village, limestone morphology forms rugged topography with seasonal dry streams and limited soil development (Haryono et al. 2009; Wijayanti and Noviani 2020). This environmental fragility heightens the ecological importance of remnant vegetation patches that serve as microrefugia for flora and fauna, while also functioning as natural regulators of soil moisture and erosion. However, biodiversity patterns in these habitats remain poorly documented, highlighting a critical knowledge gap that hinders informed conservation planning.

Environmental gradients in Bukit Cubung are further influenced by local agroforestry practices, which modify canopy cover, organic matter, and soil infiltration dynamics. When managed appropriately, these practices may help maintain ecosystem function; yet when intensified, they pose risks to groundwater quality and the stability of karst slopes. Understanding how such gradients shape ecological resilience is therefore essential for designing ecoedutourism interventions that remain sensitive to environmental limits while enabling community-based conservation.

Biodiversity in Bukit Cubung Karst area

The karst ecosystem of Bukit Cubung supports diverse plant communities adapted to the challenging conditions of thin, alkaline soils and seasonal water scarcity. Historical records indicate the area was known for endemic species such as *kecubung* (*Datura metel*) shown in Table 1, which gave the hill its name. The vegetation includes typical karst-adapted species and rehabilitated native karst plants like those documented in nearby Suaka Margasatwa Paliyan, including *bulu, preh, eko, pulai,* and *kepuh* (Figure 2).

Flora sampling across 10 permanent plots (0.1 ha total area, 10 m x 10 m per plot) identified 23 species. The biodiversity indices shown by Shannon-Wiener diversity (*H'*) 2.71 (indicating moderately high diversity; *H'* values for tropical forests range 2.0-4.0), Simpson's Dominance index (*D*) 0.185 (indicating relatively even distribution of species; *D* close to 0 indicates high evenness); species richness (*S*) 23 species in 0.4 ha; and evenness index (*J*) is 0.78 (indicating relatively balanced species abundance; J ranges 0-1, with higher values indicating greater evenness). These indices confirm that Bukit Cubung harbors moderately high botanical diversity characteristic of tropical karst ecosystems, with dominance by planted agroforestry species but significant presence of native. The Menoreh karst region specifically supports characteristic vegetation including *Tectona grandis* (teak), *Ficus* species (which serve as keystone species in karst ecosystems), and various native species critical for ecosystem stability.

Table 1. List of flora in Bukit Cubung karst area

Family	Scientific name	Local name	IUCN status
Acanthaceae	*Barleria prionitis* L.	*Landep*	Not Assessed
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	*Tabebuya*	Not Assessed
Combretaceae	*Terminalia catappa* L.	*Ketapang*	Not Assessed
Euphorbiaceae	*Acalypha wilkesiana* Müll.Arg.	*Teh-tehan*	Not Assessed
	Cnidoscolus aconitifolius (Mill.) I.M.Johnst.	*Chaya*	Not Assessed
	Codiaeum variegatum (L.) Rumph. ex A.Juss.	*Puring*	Not Assessed
Fabaceae	*Acacia auriculiformis* A.Cunn. ex Benth.	*Akasia daun lebar*	Least Concern
	Acacia sp.	*Akasia*	Least Concern
	Caesalpinia pulcherrima (L.) Sw.	*Kembang merak*	Least Concern
	Gliricidia sp.	*Gamal*	Least Concern
	Senna sp.	*Johar*	Not Assessed
	Mimosa pudica L.	*Putri malu*	Not Assessed
Lamiaceae	*Scutellaria ovata* Hill	*Sambung nyawa*	Not Assessed
	Tectona grandis L.f.	*Jati*	Least Concern
Malvaceae	*Hibiscus tiliaceus* L.	*Waru*	Least Concern
Meliaceae	*Swietenia macrophylla* King	*Mahoni*	Vulnerable
Moraceae	*Artocarpus heterophyllus* Lam.	*Nangka*	Not Evaluated
	Ficus religiosa L.	*Bodhi*	Least Concern
Myrtaceae	*Eucalyptus* sp.	*Kayu putih*	Not Assessed
Pandanaceae	*Pandanus tectorius* Parkinson	*Pandan laut*	Least Concern
Polyporaceae	*Pycnoporus sanguineus* (L.) Murrill	*Jamur kayu*	Not Assessed
Solanaceae	*Datura metel* L.	*Kecubung*	Not Assessed
Verbenaceae	*Lantana camara* L.	*Tembelekan*	Not Assessed

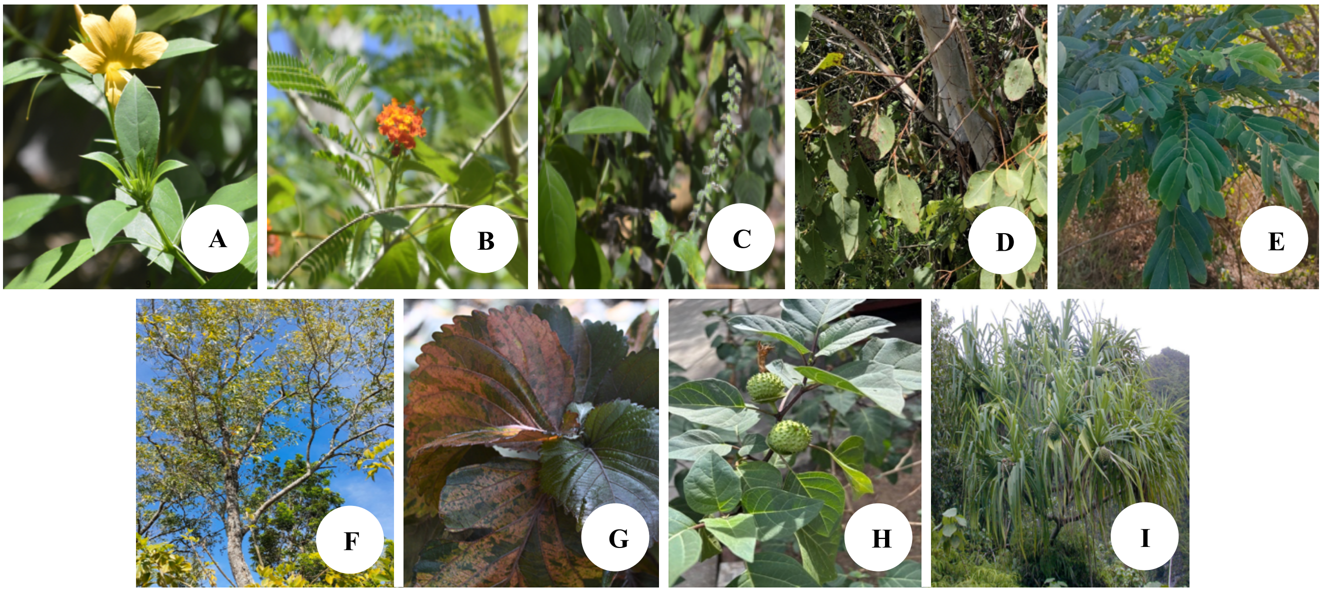

Figure 2. Flora of Bukit Cubung karst area. A. *Barleria prionitis*, B. *Lantana camara*, C. *Scutellaria ovata*, D. *Acalypha wilkesiana*, E. *Senna* sp., F. *Acacia* sp., G. *Eucalyptus* sp., H. *Datura metel*, I. *Pandanus tectorius*

Table 2. List of fauna in Bukit Cubung karst area

Taxon group	Family	Scientific name	Local name	IUCN status
Reptilia	Gekkonidae	*Gekko gecko* (Linnaeus, 1758)	*Tokek*	Least Concern
		Hemidactylus frenatus Duméril & Bibron, 1836	*Cicak rumah*	Least Concern
		Hemidactylus platyurus (Schneider, 1797)	*Cicak tembok*	Least Concern
	Agamidae	*Bronchocela jubata* Duméril & Bibron, 1837	*Bunglon surai*	Least Concern
		Draco volans Linnaeus, 1758	*Kadal terbang*	Least Concern
	Scincidae	*Eutropis multifasciata* (Kuhl, 1820)	*Kadal garis*	Least Concern
		Dasia olivacea Gray, 1839	*Kadal pohon*	Least Concern
	Colubridae	*Ahaetulla prasina* (Boie, 1827)	*Ular hijau pucuk*	Least Concern
Amphibia	Microhylidae	*Microhyla achatina* Tschudi, 1838	*Katak padi Jawa*	Least Concern
	Ranidae	*Chalcorana chalconota* (Schlegel, 1837)	*Katak hijau*	Least Concern
Arachnida	Salticidae	*Hyllus diardi* (Walckenaer, 1837)	*Laba-laba pelompat*	Not Assessed
	Vespidae	*Pseudodynerus quadrisectus* (Say, 1837)	*Tawon kertas*	Not Assessed
Insecta	Pieridae	*Phoebis sennae* (Linnaeus, 1758)	*Kupu-kupu belerang*	Not Assessed
	Nymphalidae	*Neptis hylas* Linnaeus, 1758	*Kupu-kupu pelaut*	Not Assessed
	Acrididae	*Locusta migratoria* (Linnaeus, 1758)	*Belalang kembara*	Least Concern
	Calliphoridae	*Mesembrinus elongatus* (Röding, 1789)	*Lalat hijau*	Not Assessed
	Libellulidae	*Orthetrum sabina* (Drury, 1773)	*Capung hijau*	Least Concern

For karst ecosystems, H' values >2.5 indicate functionally diverse communities with multiple trophic pathways and habitat niches—a marker of ecosystem resilience under disturbance. Simpson's Dominance index (D) identifies whether one or a few species disproportionately dominate (D>0.5 indicates dominance, suggesting degradation; D<0.3 indicates balanced community, suggesting integrity). Together, these indices reveal whether Bukit Cubung harbors the structural complexity typical of healthy karst: high species richness, even abundance distribution, and absence of dominance by invasive or disturbance-tolerant species. If tourism or degradation impacts occur, declining H' or increasing D would signal ecosystem stress—allowing adaptive management responses.

Fauna inventory documented 17 species consisting mainly of reptiles, amphibians, insects, and spiders (Table 2). The fauna diversity index was H' = 2.43, with a dominance index of 0.24 and evenness of 0.82, indicating moderate heterogeneity across the surveyed non-avian fauna. Birds were surveyed during fieldwork, but their records were not included in diversity calculations because detections were too limited to support a robust index-based analysis. Based on the results, fauna diversity was lower than flora diversity, consistent with tropical forest patterns where plants show higher diversity than animals at equivalent spatial scales.

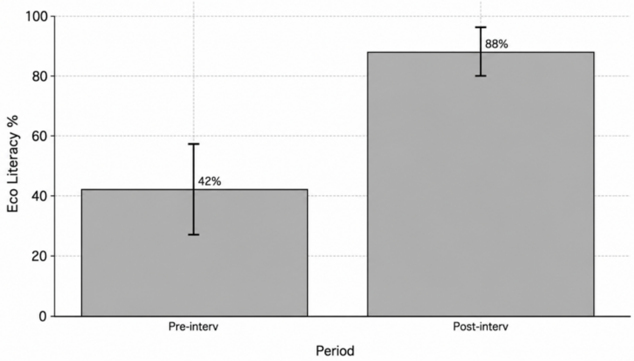

Figure 3. Ecological literacy improvement during the program. Error bars indicate standard deviation. Data from structured 20-item knowledge assessments conducted before and after six biodiversity literacy workshops

Biodiversity awareness and local knowledge

After the biodiversity workshops, participants demonstrated higher species recognition and ecological understanding. Post-training results showed significant improvement in community knowledge. Identification accuracy for local tree species increased from 44% to 86%, while knowledge of faunal species rose from 36% to 82%. Participants expressed new awareness of how vegetation supports karst hydrology and microhabitats for fauna. The Book of Biodiversity became a primary reference for both local guides and visiting students, transforming biodiversity documentation into a learning instrument for sustainable tourism. Its integration into eco-edutourism packages strengthened the scientific and educational dimension of the site.

Figure 3 clearly demonstrates the significant improvement in ecological literacy from 42.1% (±15% SD) in pre-intervention to 87.8% (±8% SD) in post-intervention among the 20 participants ($t(19) = 8.32$, $p<0.001$; Cohen's $d = 1.85$). The large effect size indicates improvements exceeded what would be expected from repeated testing or social desirability alone. The 45.7 percentage-point gain was consistent across all knowledge domains (flora +42%, fauna +46%, ecosystem functions +50%, conservation significance +48%), suggesting the integrated 12-week program successfully addressed multiple dimensions of ecological understanding. Notably, 16 of 20 participants (80%) achieved post-test scores >80%, indicating broad competency development rather than improvement driven by high-performing outliers.

Community-based management system

As a management system, the community created a committee, a small group consisting of people with an interest in ecotourism. Eco-edutourism Committee was formally established, introducing a revenue-sharing scheme allocating 10% of income for conservation and environmental education. The newly formed Bukit Cubung Ecoedutourism Committee formalized tourism governance with defined roles, environmental codes, and visitor limits based on site carrying capacity. Visitor safety and hygiene protocols followed Indonesia's CHSE (Cleanliness, Health, Safety, Environment) standards. The participatory structure improved governance transparency and local ownership. Recognizing that effective biodiversity management requires collaboration across sectors, the initiative brings together government agencies, local communities, non-governmental organizations (NGOs), and the private sector. This inclusive strategy fosters shared responsibility and innovation, ensuring that diverse perspectives contribute to Indonesia's conservation efforts.

Discussion

Ecological literacy as foundation for conservation

The significant improvement in ecological literacy (from 42.1% to 87.8%) demonstrates that community-based training can rapidly enhance knowledge of local biodiversity and ecosystem functions. The findings indicate that biodiversity inventory can serve not only as baseline ecological data but also as a practical educational resource within a participatory eco-edutourism model. In Bukit Cubung, the integration of flora and fauna documentation with literacy activities helped make biodiversity more visible, understandable, and socially relevant to local participants. The professional identity shifts documented in interviews wherein 90% of participants self-identified as "biodiversity educators" by study end suggest that literacy gains translated into internalized role identity, a stronger predictor of sustained behavior than episodic knowledge gain alone. This aligns with conservation psychology research showing that environmental identity is among the strongest predictors of pro-conservation behavior.

Compared to conservation education meta-analyses (finding typical effect sizes Cohen's d = 0.4-0.8), our d = 1.85 is notably strong, likely reflecting: (i) integrated PAR approach allowing community voice in curriculum design; (ii) intensive contact (12 weeks, multiple weekly sessions); (iii) authentic application context (immediately usable for guiding); (iv) relatively small group enabling personalized feedback.

Biodiversity as the core of eco-edutourism

The integration of species data into eco-edutourism programs enhances the scientific and experiential value of the site. The flora-fauna inventory provided interpretive content for nature trails and educational signage, linking each landscape element to biodiversity narratives. This aligns with the Global Biodiversity Framework's Target 19 on knowledge sharing and Target 2 on ecosystem restoration (CBD 2022). Similar models in Thailand and Vietnam have shown that community empowerment is critical to karst ecosystem resilience. The Bukit Cubung initiative illustrates how a local biodiversity inventory can serve as a living foundation for education and sustainable tourism.

The diversity index (H' = 2.71 for flora and H' = 2.43 for fauna) indicates a moderately high ecological heterogeneity typical of tropical karst environments, supporting the notion that karst ecosystems harbor unique adaptive species (Culver and Pipan 2019). The Shannon-Wiener index measures species diversity by accounting for both species richness (number of species) and evenness (distribution of individuals among those species). Values around 2.5 to 3.5 suggest diverse and evenly distributed communities, which is typical for well-functioning tropical karst environments that provide a variety of microhabitats due to their complex geological structure. This heterogeneity supports a wide range of species, including several that are uniquely adapted to karst conditions, such as specialized flora that thrive in thin, alkaline soils and fauna that utilize the limestone caves and springs for habitat. Such biodiversity richness underlines the importance of karst systems as refugia of endemic and adaptive species that contribute to the overall ecological resilience of tropical landscapes. Maintaining this heterogeneity is crucial for effective conservation strategies, as it sustains both common and rare species within the karst ecosystem.

Indonesia's IBSAP 2025-2045 identifies community-based ecoedutourism in karst regions as a critical pathway for biodiversity mainstreaming. Bukit Cubung exemplifies this opportunity: a karst area with documented endemic species, engaged local institutions (village government, tourism group, youth organizations), and opportunity for demonstrating integrated conservation-education-livelihood models. However, translating these commitments into local action requires demonstrated, replicable models linking biodiversity science, community learning, sustainable livelihoods, and participatory governance.

Eco-edutourism as a conservation strategy: Theory and evidence

Ecotourism, defined as responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education, has emerged as a potential mechanism for reconciling biodiversity conservation with rural livelihood development (Fennell 2020). Eco-edutourism—a variant emphasizing environmental education, experiential learning, and community participation alongside ecological conservation—extends ecotourism frameworks by embedding learning as a primary outcome rather than peripheral benefit.

Empirical evidence demonstrates eco-edutourism's conservation potential under specific conditions. Successful community-based ecotourism initiatives in Costa Rica increased protected area effective management while generating USD 2.5-3.5 billion annually (UNWTO 2021). Thai community-based ecotourism in Khao Yai National Park strengthened local stewardship behaviors and reduced poaching by 60% through participatory management (Kontogeorgopoulos 2005). Vietnamese karst ecotourism in Phong Nha-Ke Bang enhanced local ecological knowledge and supported habitat restoration through tourism revenue allocation (Pham et al. 2020). However, the broader ecotourism literature reveals critical limitations: approximately 60-70% of community-based ecotourism ventures fail within 5-7 years due to insufficient market access, inadequate governance institutions, and limited authentic community control. Most existing eco-edutourism models remain tourism-centric, prioritizing visitor experience and revenue generation over conservation outcomes and genuine community empowerment.

The role of eco-edutourism in biodiversity mainstreaming

Eco-edutourism creates an interface between biodiversity and livelihoods, providing tangible incentives for conservation. The ecoprint initiative demonstrated that sustainable use of native plants can generate economic value without harming ecosystems, a local translation of GBF Goal A (reducing threats to biodiversity) and Goal B (sustainable use and benefit sharing). Comparable successes in Thailand and Vietnam show that integrating biodiversity education into community-based tourism strengthens social capital and local stewardship (Kontogeorgopoulos 2005; Pham et al. 2020).

By transforming biodiversity knowledge into experience, ecoedutourism functions as a social instrument for conservation. The ecoprint initiative exemplifies how plant diversity can generate both ecological awareness and economic value. It also promotes the sustainable use of Non-Timber Forest Products (NTFPs), echoing the Convention on Biological Diversity's (CBD) principle of equitable benefit sharing.

Challenges and future directions

While results are promising, the sustainability of eco-edutourism depends on maintaining ecological integrity and market viability. Continuous biodiversity monitoring, capacity building, and partnerships with academia and conservation NGOs are needed. Integrating biodiversity data into the district's spatial planning could ensure long term ecosystem protection.

The Bukit Cubung eco-edutourism initiative demonstrates that biodiversity documentation can catalyze conservation-driven tourism models. As a replicable model, it bridges local action and global commitments to biodiversity protection, contributing to SDGs 4, 8, 11, 12, and 15. The integration of flora and fauna inventories into educational programs transformed local perceptions and practices toward sustainability. Protecting karst biodiversity thus requires not only scientific management but also the empowerment of the communities who live within it. This case reinforces that global biodiversity goals can only be achieved through local participation, where communities are not passive beneficiaries but active custodians of nature. The model developed in Bukit Cubung offers a replicable pathway for other karst regions in Indonesia and beyond to bridge biodiversity conservation, education, and sustainable development. Integration of Bukit Cubung's biodiversity data into the Kulon Progo District like Environmental Information System (SIM-LH) is recommended to support adaptive management. Collaboration with universities and NGOs should continue to ensure scientific integrity and innovation in biodiversity education.

In conclusion, this study shows that participatory eco-edutourism in Bukit Cubung can link biodiversity conservation with community empowerment through a combination of biodiversity documentation, ecological literacy enhancement, and local governance development. The identification of 23 flora species and 17 fauna species, together with improved literacy among 20 participants, indicates that biodiversity-based educational tourism can support both ecological awareness and community participation in conservation. In fragile karst landscapes, eco-edutourism therefore has potential to function as a locally grounded conservation platform when supported by clear biodiversity information, participatory learning, and community-based management.

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REFERENCES

Angulo B, Morales T, Uriarte JA, Antigüedad I. 2013. Implementing a comprehensive approach for evaluating significance and disturbance in protected karst areas to guide management strategies. J Environ Manag 130: 386-396. https://doi.org/10.1016/j.jenvman.2013.08.057.

Arif R, Mandeli RS, Lestari DA, Hanriesta R. 2024. Threats of mining activities and karst landscape management strategies in Indonesia. AIP Conf Proc 3001: 080019. https://doi.org/10.1063/5.0184145.

Canedoli C, Ficetola GF, Corengia D, Tognini P, Ferrario A, Padoa-Schioppa E. 2022. Integrating landscape ecology and the assessment of ecosystem services in the study of karst areas. Landsc Ecol 37 (1): 1-19. https://doi.org/10.1007/s10980-021-01351-2.

Chen A, Ng Y, Zhang E, Tian M. 2020. Karst cave tourism landscape. In: Chen A, Ng Y, Zhang E, Tian M (eds). Dictionary of Geotourism. Springer, Singapore. https://doi.org/10.1007/978-981-13-2538-0_1254.

Chen S, Yang Z, Wu Y, Li Y, Meng L, Chen L, Chen Y, Shao X, Sui M, Zhang G, Chen D, He Y, Zang L, Liu Q. 2024a. Species prefer to shifting niche positions rather than expanding niche breadth to adapt to the heterogeneous karst forests. For Ecosyst 11: 100247. https://doi.org/10.1016/j.fecs.2024.100247.

Chen T, Wang Y, Peng L. 2024b. Exploring social-ecological system resilience in South China Karst: Quantification, interaction and policy implication. Geogr Sustain 5 (2): 289-301. https://doi.org/10.1016/j.geosus.2024.01.003.

Chen Y, Cheng C, Xiong K, Rong L, Zhang S. 2024c. Quantifying the biodiversity and ecosystem service outcomes of karst ecological restoration: A meta-analysis of South China Karst. Catena 245: 108278. https://doi.org/10.1016/j.catena.2024.108278.

Culver DC, Pipan T. 2019. The Biology of Caves and Other Subterranean Habitats. 2nd ed. Oxford University Press, Oxford.

De Waele J, Gutiérrez F. 2022. Karst Hydrogeology, Geomorphology and Caves. 1st ed. Wiley, Hoboken. https://doi.org/10.1002/9781119605379.

Fennell DA. 2020. Ecotourism. 5th ed. Routledge, London. https://doi.org/10.4324/9780429346293.

Goldscheider N. 2019. A holistic approach to groundwater protection and ecosystem services in karst terrains. Carbonates Evaporites 34: 1241-1249. https://doi.org/10.1007/s13146-019-00492-5.

Government of Indonesia. 2024. Indonesian Biodiversity Strategy and Action Plan 2025-2045. Government of Indonesia, Jakarta.

Haryono E, Adji TN, Widyastuti M, Trijuni S. 2009. Atmospheric carbon dioxide sequestration trough karst denudation process: Preliminary estimation from Gunung Sewu Karst. In: Proceeding of International Seminar on Achieving Resilient-Agriculture to Climate Change Through the Development of Climate-Based Risk Management Scheme. PERHIMPI, Bogor, 17-19 December 2009.

Kaivo-oja J, Panula-Ontto J, Vehmas J, Luukkanen J. 2014. Relationships of the dimensions of sustainability as measured by the sustainable society index framework. Intl J Sustain Dev World Ecol 21 (1): 39-45. https://doi.org/10.1080/13504509.2013.860056.

Kiss A. 2004. Is community-based ecotourism a good use of biodiversity conservation funds? Trends Ecol Evol 19 (5): 232-237. https://doi.org/10.1016/j.tree.2004.03.010.

Kumilamba G, Liu S, Wang Z, Li J, Zhan Y, Lu X. 2025. Understory biodiversity in karst forests: A comparison of pure (*Pinus massoniana*) and mixed forests in Guiyang, China. For Ecol Manag 588: 122753. https://doi.org/10.1016/j.foreco.2025.122753.

Ma B, Jing J, Liu B, Xu Y, Dou S, He H. 2022. Spatiotemporal variation of net primary productivity influenced by climatic variables in the karst area of China. Geocarto Intl 38: 1-20. https://doi.org/10.1080/10106049.2022.2129845.

Mičetić Stanković V. 2023. Biodiversity in karst landscapes: Introduction to the special issue. Diversity 15 (3): 408. https://doi.org/10.3390/d15030408.

Scheyvens R. 1999. Ecotourism and the empowerment of local communities. Tour Manag 20 (2): 245-249. https://doi.org/10.1016/S0261-5177(98)00069-7.

Sulistiyowati E, Setiadi, Haryono E. 2021. Karst and conservation research in Indonesia and its implication to education. J Phys Conf Ser 1796 (1): 012071. https://doi.org/10.1088/1742-6596/1796/1/012071.

Widodo S, Hidayat K, Sukesi K, Yuliati Y. 2024. Farmer household livelihood strategy around karst area in Tuban, East Java. Habitat 35 (3): 304-317. https://doi.org/10.21776/ub.habitat.2024.035.3.25.

Wijayanti P, Noviani R. 2020. Disaster Threats in the Gunungsewu Karst Area and Mitigation Efforts in the Framework of Disaster Risk Reduction Review of the Hydrological and Geomorphological Aspects. In Social, Humanities, and Educational Studies (SHEs): Conference Series. https://doi.org/10.20961/shes.v3i1.45067.

Zupan Hajna N. 2025. Caves and karst in global sustainability: The case for an international day. Nature-Based Solutions 8: 100282. https://doi.org/10.1016/j.nbsj.2025.100282.