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Research Paper

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HERPETOFAUNAL COMMUNITIES IN BUTUAN CITY, PHILIPPINES: A SATOYAMA-SATOUMI APPROACH TO BIODIVERSITY ASSESSMENT

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ARTICLE HIGHLIGHTS

- Community-managed landscapes and seascapes support endemic and native amphibian and reptile species
- Forty-three amphibian and reptile species were recorded in Butuan City.
- The landscape and seascape are dominated by lowland amphibian and reptile species.
- This study provides baseline data for biodiversity conservation and monitoring.

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ABSTRACT

This study provides the first systematic assessment of amphibians and reptiles within the Satoyama-Satoumi landscape-seascape mosaic of Butuan City, Agusan del Norte, Philippines. Herpetofaunal surveys were conducted across six habitat types in Barangays Tungao (agroforest, grassland-agroecosystem, riparian) and Masao (landward, middleward, and seaward mangroves) using habitat-stratified transects, diurnal and nocturnal searches, passive trapping, and standardized field recording. A total of 43 species were documented, comprising 14 amphibians and 29 reptiles, including 24 Philippine endemics, of which 13 species are Mindanao Faunal Region endemics. Three invasive amphibians were also recorded. Species diversity was higher in Tungao (H' = 2.57) than in Masao (H' = 1.94), reflecting contrasts in habitat condition and disturbance intensity. Most species were classified as Least Concern (n = 36). However, the presence of Near Threatened (n = 1) and nationally recognized Other Threatened Species (n = 11) highlights the conservation importance of the area. Distinct microhabitat associations from forest floors and riparian zones to mangroves and human-modified areas emphasize the ecological heterogeneity supporting these assemblages. This baseline inventory demonstrates that community-managed Satoyama–Satoumi habitats serve as important secondary refugia for herpetofauna and highlights the need for sustained monitoring and habitat protection in Butuan City.

Keywords: herpetofauna, invasive alien species, landscape-seascape, Philippine endemics

INTRODUCTION

Human-modified landscapes are increasingly recognized as critical spaces for biodiversity conservation, especially in regions undergoing rapid land-use change. As agricultural expansion, urbanization, and habitat conversion intensify globally, species survival increasingly depends on the ecological integrity of multi-use environments (Harisena *et al.* 2025). Human-wildlife coexistence is increasing as human expansion fragments natural habitats. While some species adapt to human-modified landscapes, this overlap can lead to human–wildlife conflicts that threaten both humans and animals. In residential areas, wildlife such as snakes may appear more frequently, increasing the likelihood of human-snake encounters and potential conflict (Khoerunisa *et al.* 2021). Habitat loss and urban expansion also force wildlife to move into nearby landscapes in search of resources, with factors such as slope, distance from settlements, and remaining forest patches influencing their distribution (Maulahila *et al.* 2025). Consequently, the growing overlap between human activities and wildlife habitats heightens the risk of conflict.

The Satoyama-Satoumi framework, rooted in traditional Japanese practices that emphasize sustainable interactions between people and nature, offers a valuable lens for understanding how biodiversity can persist within mosaics of agroforestry systems, secondary forests, riparian zones, and coastal ecosystems (Saito 2020). Although the Philippines shares comparable community-managed production landscapes, scientific assessments applying Satoyama-Satoumi principles to local biodiversity patterns remain scarce.

Amphibians and reptiles serve as sensitive biological indicators in such environments. (Plaza & Sanguila 2015; Pilliod *et al.* 2022; Abdullah *et al.* 2023). Highly disturbed habitats tend to have reduced abundance and species diversity of reptiles and amphibians (Maulida *et al.* 2025). Their physiological dependence on temperature, moisture, and microhabitat integrity makes them highly vulnerable to environmental disturbance, while their functional roles as predators and prey maintain trophic balance in both terrestrial and aquatic ecosystems (Valencia-Aguilar *et al.* 2013; Pilliod *et al.* 2022). Despite Mindanao's recognized importance as a biodiversity frontier (Sanguila *et al.* 2016; Plaza *et al.* 2025; Sanguila *et al.* 2026), herpetofaunal research in northeastern Mindanao has disproportionately focused on protected forests, mountain ecosystems, and riverine systems, leaving peri-urban landscapes, agroecosystems, and mangrove-dominated seascapes comparatively understudied.

Butuan City hosts an ecologically diverse gradient of habitats that aligns strongly with the Satoyama-Satoumi concept. Barangay Tungao comprises a mosaic of agroforestry patches, riparian corridors, cultivated lands, and remnants of lowland secondary forest (Ruales *et al.* 2023). In contrast, Barangay Masao represents a complementary seascape characterized by landward, middleward, and seaward mangrove zones that transition into fishing grounds and estuarine waterways (Buhay *et al.* 2023). These landscapes and seascapes are central to local livelihoods and resource use, yet their contribution to sustaining herpetofaunal communities remains undocumented.

Given the region's rapid land-use transformations, understanding species richness, habitat association, and the influence of anthropogenic activities across these interconnected ecosystems is vital. Baseline information is especially needed for endemic and threatened taxa whose distributions are shaped by microhabitat availability, environmental gradients, and disturbance regimes. Moreover, the presence of invasive species, shifting agricultural practices, and resource extraction in these habitats necessitates an ecological inventory that can inform local conservation planning and community-based management.

This study provides the first systematic assessment of amphibian and reptile assemblages within the Satoyama-Satoumi landscape-seascape mosaic of Butuan City, Agusan del Norte, Philippines. Specifically, this study aimed to: 1) document species composition and distribution across agroforest, agroecosystem-grassland, riparian, and mangrove habitats; 2) describe patterns of diversity, endemism, and conservation status; and 3) examine habitat associations in relation to human influence. By establishing this baseline, the study contributes to ongoing biodiversity monitoring efforts in northeastern Mindanao and highlights the potential of community-managed landscapes to function as secondary refugia for herpetofauna amid increasing environmental pressures.

MATERIALS AND METHODS

Study Area

The assessment was conducted in two barangays of Butuan City, Agusan del Norte, Philippines, i.e., Tungao and Masao, representing the terrestrial Satoyama landscape and the coastal Satoumi seascape, respectively (Fig. 1). These areas form a mosaic of multi-use habitats shaped by agricultural practices, community-managed land-use systems, and aquatic resource extraction.

Barangay Tungao (Satoyama Landscape)

Located in the southern portion of Butuan City, Philippines, Tungao encompasses approximately 15,700 ha, of which ~13,000 ha is allocated for agriculture and agroforestry (Fig. 2). The area consists of lowland secondary forest, sloping agroforest zones, riparian corridors, grasslands, and cultivated patches. Dominant vegetation includes *Shorea contorta*, *Agathis philippinensis*, *Tectona grandis*, *Artocarpus elasticus*, *Falcataria falcata*, *Acacia mangium*, *Spathodea campanulata*, and *Swietenia macrophylla* (Ruales *et al.* 2023). This structurally diverse environment creates a heterogeneous matrix suitable for herpetofaunal occupancy.

Barangay Masao (Satoumi Seascape)

Masao lies along the western coastal zone of Butuan City, Philippines and covers approximately 534 ha composed of mangrove forests, estuarine waterways, aquaculture ponds, grasslands, and coconut–nipa plantations (Fig. 3). Land use is dominated by agriculture (70%), followed by residential areas (18%) and timberland (10%). Common mangrove species include *Rhizophora apiculata*, *R. mucronata*, *Sonneratia alba*, *Nypa fruticans*, *Avicennia alba*, and *A. officinalis* (Buhay *et al.* 2024). These vegetation assemblages form a continuum from landward to seaward zones, providing diverse ecological niches for amphibians and reptiles.

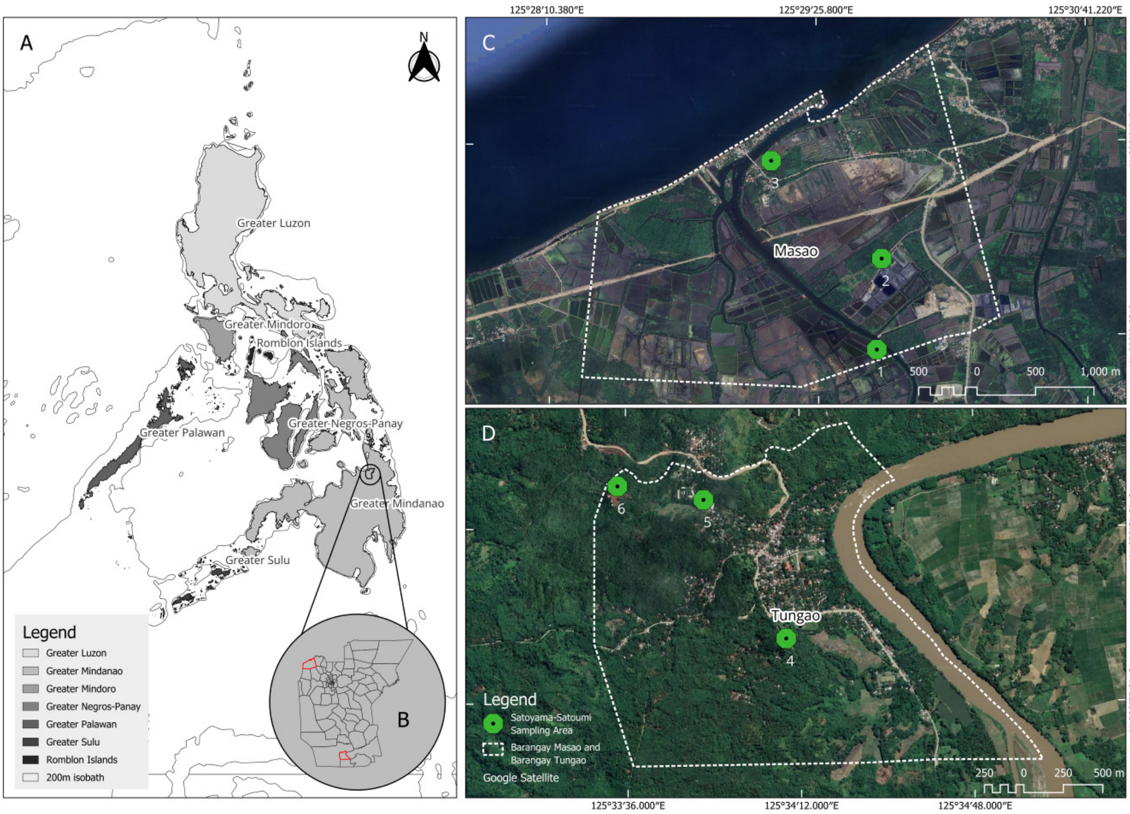

Figure 1 Map of the study area in the Satoyama-Satoumi Landscape and Seascape of Butuan City, Agusan del Norte, Philippines

Notes: A = Major Philippine, Pleistocene Aggregate Island Complexes (PAICs); B = Butuan City, Agusan del Norte; C = Barangay Masao-a Satoumi Seascape; and D = Barangay Tungao-a Satoyama Landscape.

Figure 2 The Satoyama Landscape of Butuan City, Agusan del Norte, Philippines
Notes: A = aerial view of the different ecosystem types in Barangay Tungao; B = agroforest; C = grassland and agroecosystem; D = riparian ecosystem. Photo credit: J. Flores and UPOU EIDR bSMART Program CC BY-NC 4.0.

Figure 3 The Satoumi Seascape of Butuan City, Agusan del Norte, Philippines
Notes: A = aerial view of the seaward ecosystem type in Barangay Masao; B = middleward ecosystem type; and C = landward ecosystem type. Photo credit: Jabez Flores.

Sampling Design and Herpetofaunal Survey

Herpetofaunal sampling followed a habitat-stratified design consistent with the Manual on Biodiversity Assessment and Monitoring System (BAMS) for Terrestrial Ecosystems of DENR–BMB and GIZ (Cruz *et al.* 2017). Six vegetation types were surveyed across Tungao (agroforest, agroecosystem-grassland, and riparian zones) and Masao (seaward, middleward, and landward mangrove zones). A 1-km transect was established within each habitat type, following BAMS recommendations for vertebrate assessments.

To supplement systematic transect walks, opportunistic encounters outside the established transects, such as in forest clearings, temporary pools, agricultural edges, and riparian margins, were also documented to increase species detectability (Cruz *et al.* 2017).

Survey Period and Effort

Field surveys were conducted during both dry and wet periods, January to February 2022 and June to July 2022, to capture seasonal variability in herpetofaunal activity. In accordance with the BAMS temporal sampling framework, each transect was surveyed under diurnal (09:00 – 11:00 h) and nocturnal (19:00 – 22:00 h) periods and across varying weather scenarios to maximize species detectability. This temporal and environmental breadth ensured adequate documentation of weather-dependent and seasonally active species.

Herpetofaunal Sampling

Herpetofaunal sampling combined active nocturnal searches with passive trapping following BAMS protocols (Cruz *et al.* 2017). Active search-and-capture surveys were performed from 19:00 PM to 21:00 PM, the recommended period for amphibian and reptile detection. Trained observers walked each 1-km transect slowly, scanning up to five meters on either side using headlamps and hand torches. Individuals were detected by eye-shine, movement, perched posture, or acoustic cues from calling anurans. Microhabitats such as leaf litter, tree buttresses, bamboo clumps, decomposing logs, understory vegetation, riparian edges, and mangrove root systems were carefully examined. Captured individuals were gently restrained, identified, photographed (Canon EF-S 18-135mm f/3.5-5.6 IS USM lens), measured when necessary, and released immediately at the point of capture.

To complement active searching, 12 pitfall traps were installed per transect and operated continuously for 24 hours. Traps were placed in ground-level microhabitats including leaf-littered forest floors, grassland edges, and moist mangrove depressions. Following BAMS guidelines, traps were checked each morning at approximately 0500 h to minimize stress or mortality. Captured individuals were identified, processed, and released promptly. This combination of active and passive methods increased the likelihood of detecting fossorial, cryptic, and ground-dwelling species.

Capture, Handling, and Measurements

Specimens requiring closer examination were captured manually or with snake tongs to ensure researcher safety and minimize stress to the animals. Handling procedures followed ethical guidelines for non-lethal vertebrate sampling outlined in BAMS (Cruz *et al.* 2017). Morphometric measurements, including snout-vent length (SVL), total length (TL), head length (HL), tail length (TailL), and body weight (BW), were taken using standard herpetological techniques with reference to anatomical diagrams provided in the BAMS manual. After processing and photographic documentation, all individuals were released at the exact point of capture.

Field Data Recording

Field observations were documented using standardized datasheets adapted from BAMS to ensure consistency across sampling sites. Recorded information included species identity, number of individuals, date and time, observer(s), GPS coordinates, weather conditions, vegetation type, microhabitat following classification and description of Sanguila *et al.* (2021), observed behavior, and any relevant ecological notes. These uniform data facilitated reliable comparisons of herpetofaunal assemblages across the Satoyama-Satoumi gradient.

Species Identification and Conservation Status

Species identification was based on high-resolution photographs and diagnostic morphological features, with verification using key Philippine taxonomic references including Brown & Alcala (1980), Alcala (1986), Alcala and Brown (1998), Brown *et al.* (2000, 2008, 2009, 2011), Diesmos *et al.* (2015, 2020), and Sanguila *et al.* (2016). Conservation status was assessed following the International Union for Conservation of Nature's Red List of Threatened Species (IUCN), version 2025-2, while national categories adhered to the Department of Environment and Natural Resources Administrative Order 2019-09 (DENR DAO 2019-09). This combined morphological and literature-based approach ensured accurate documentation and evaluation of species recorded across the study area.

Biodiversity Attributes

Indices of biodiversity such as Species Richness, Abundance, Dominance, Evenness and Shannon's Diversity were computed using PAST® software.

RESULTS AND DISCUSSION

Species Composition

The herpetofauna assessment conducted in the Satoyama landscape (Barangay Tungao) and Satoumi seascape (Barangay Masao) of Butuan City recorded a total of 43 species, comprising 14 amphibians, and 29 reptiles (Table 1; Fig. 4). These represented seven amphibian families in 11 genera and 14 reptile families in 27 genera (Table 1; Figs. 4, 5, & 6).

Table 1 Herpetological fauna in Satoyama-Satoumi Landscape and Seascape in Butuan City, Agusan del Norte, Philippines summarized by taxa, distribution, conservation status (IUCN 2025-2 and DAO 2019-09), and observed sampling area

Species	Endemicity	Conservation Status		Barangay Tungao	Barangay Masao
		IUCN Status (2025-2), Population Trend	DAO 2019-09		
AMPHIBIANS (Frogs)					
Bufonidae					
1. *Rhinella marina*	IAS	LC, ↑	OWS	✓	✓
Ceratobatrachidae					
2.*Platymantis dorsalis*	PE	LC, ↓	OWS	✓	
Dicroglossidae					
3. *Fejervarya moodiei*	NE	LC, ?	OWS		
4. *Fejervarya vittigera*	PE	LC, ↓	OWS	✓	✓
5. *Limnonectes leytensis*	PE	LC, ↓	OWS	✓	
6. *Limnonectes magnus*	MFRE	NT, ↓	OTS	✓	✓
7. *Hoplobatrachus rugulosus*	IAS	LC, ↓	OWS	✓	✓
8. *Occidozyga laevis*	PE	LC, ↓	OWS	✓	
Megophyridae					
9. *Pelobatrachus stejnegeri*	MFRE	LC, ?	OTS	✓	
Microhylidae					
10. *Kaloula picta*	PE	LC, -	OWS	✓	✓
11. *Kaloula pulchra*	IAS	LC, -	OWS	✓	✓
12. *Kalophrynus sinensis*	MFRE	LC, ?	OWS	✓	
Ranidae					
13. *Pulchrana grandocula*	MFRE	LC, -	OWS	✓	
Rhacophoridae					
14. *Polypedates leucomystax*	NE	LC, -	OWS	✓	✓
REPTILES (Lizards)					
Acrochordidae					
15. *Acrochordus granulatus*	NE	LC, ↓	OWS		✓
Agamidae					
16. *Draco bimaculatus*	MFRE	LC, -	OWS	✓	
17. *Gonocephalus* cf. *interruptus*	PE	LC, -	OTS	✓	

Species	Endemicity	Conservation Status: IUCN Status (2025-2), Population Trend	Conservation Status: DAO 2019-09	Barangay Tungao	Barangay Masao
18. *Gonocephalus* sp.	-	-	-	✓	
19. *Hydrosaurus pustulatus*	PE	LC, ↓	OTS	✓	
Gekkonidae					
20. *Cyrtodactylus agusanensis*	MFRE	LC, ?	OWS	✓	
21. *Gekko gecko*	NE	LC, ?	OTS	✓	✓
22. *Hemidactylus frenatus*	NE	LC, -	OWS	✓	✓
23. *Ptychozoon intermedium*	MFRE	LC, ↓	OWS	✓	
Scincidae					
24. *Brachymeles orientalis*	MFRE	LC, ?	OWS	✓	
25.*Eutropis multifasciata*	NE	LC, -	OWS	✓	✓
26. *Eutropis multicarinata*	PE	LC, -	OWS	✓	✓
27. *Lamprolepis smaragdina philippinica*	PE	NE, ?	OWS	✓	✓
28. *Pinoyscincus abdictus abdictus*	MFRE	LC, -		✓	
29. *Tropidophorus misaminius*	MFRE	LC, -	OWS	✓	
Varanidae					
30. *Varanus cumingi*	MFRE	LC, ↑	OTS	✓	✓
REPTILES (Snakes)					
Acrochordidae					
31. *Acrochordus granulatus*	NE	LC, ↓	OWS		✓
Colubridae					
32. *Ahaetulla prasina preocularis*	NE	NE, ?	OWS	✓	
33. *Chrysopelea paradisi variabilis*	NE	NE, ?	OWS	✓	
34. *Coelognathus erythrurus erythrurus*	NE	NE, ?	OTS	✓	✓
35. *Dendrelaphis marenae*	NE	LC, -	OTS	✓	
36. *Lycodon capucinus*	NE	LC, -	-	✓	
Elapidae					
37. *Naja samarensis*	MFRE	LC, ↓	OTS	✓	
Homalopsidae					
38. *Cerberus schneiderii*	NE	LC, ?	OWS		✓
Lamprophiidae					
39. *Oxyrhabdium modestum*	MFRE	LC, -	OWS	✓	
Pythonidae					
40. *Malayopython reticulatus*	NE	LC, ?	OTS	✓	✓
Typhlopidae					
41. *Indotyphlops braminus*	NE	LC, ↑	OWS	✓	✓
Viperidae					
42.*Trimeresurus flavomaculatus*	PE	LC, ↓	OTS	✓	
REPTILES (Turtles)					
Geoemydidae					
43. *Cuora philippinensis*	PE	NE, ?	NE	✓	

Notes: Endemicity: MFRE = Mindanao Faunal Region Endemic; PE = Philippine Endemic; NE = Non-Endemic; IAS = Invasive Alien Species. IUCN Conservation Status: NT = Near Threatened; LC = Least Concern; NE = Not Evaluated. Population Trend: ↑ = Increasing; ↓ =Decreasing; - = Stable; ? = Unknown. Philippine Red List Status (DAO2019-09): OWS = Other Wildlife Species; OTS = Other Threatened Species.

Figure 4 Recorded frog species in the Satoyama-Satoumi Landscape and Seascape of Butuan City, Agusan del Norte, Philippines

Notes: A = *Limnonectes magnus*; B = *Polypedates leucomystax*; C = *Fejervarya vittigera;* D = *Kalophrynus sinensis*; E = *Occidozyga laevis*; F = *Kaloula pulchra*; G–H = *Pelobatrachus stejnegeri*; I = *Platymantis dorsalis*; J = *Pulchrana grandocula*; K = *Hoplobatrachus rugulosus*; and L = *Rhinella marina.*

Figure 5 Recorded lizard and turtle species in the Satoyama-Satoumi Landscape and Seascape of Butuan City, Agusan del Norte, Philippines

Notes: A = *Ptychozoon intermedium*; B = *Eutropis multicarinata*; C = *Eutropis multifasciata*; D = *Draco bimaculatus*; E = *Varanus cumingi*; F = *Brachymeles orientalis*; G = *Cyrtodactylus agusanensis*; H = *Tropidophorus misaminius*; I = *Pinoyscincus abdictus*; J = *Hydrosaurus pustulatus*; K = *Lamprolepis smaragdina philippinica*; L = *Gekko gecko*; M. *Hemidactylus frenatus*; N = *Gonocephalus interruptus*; and O = *Cuora philippinensis*.

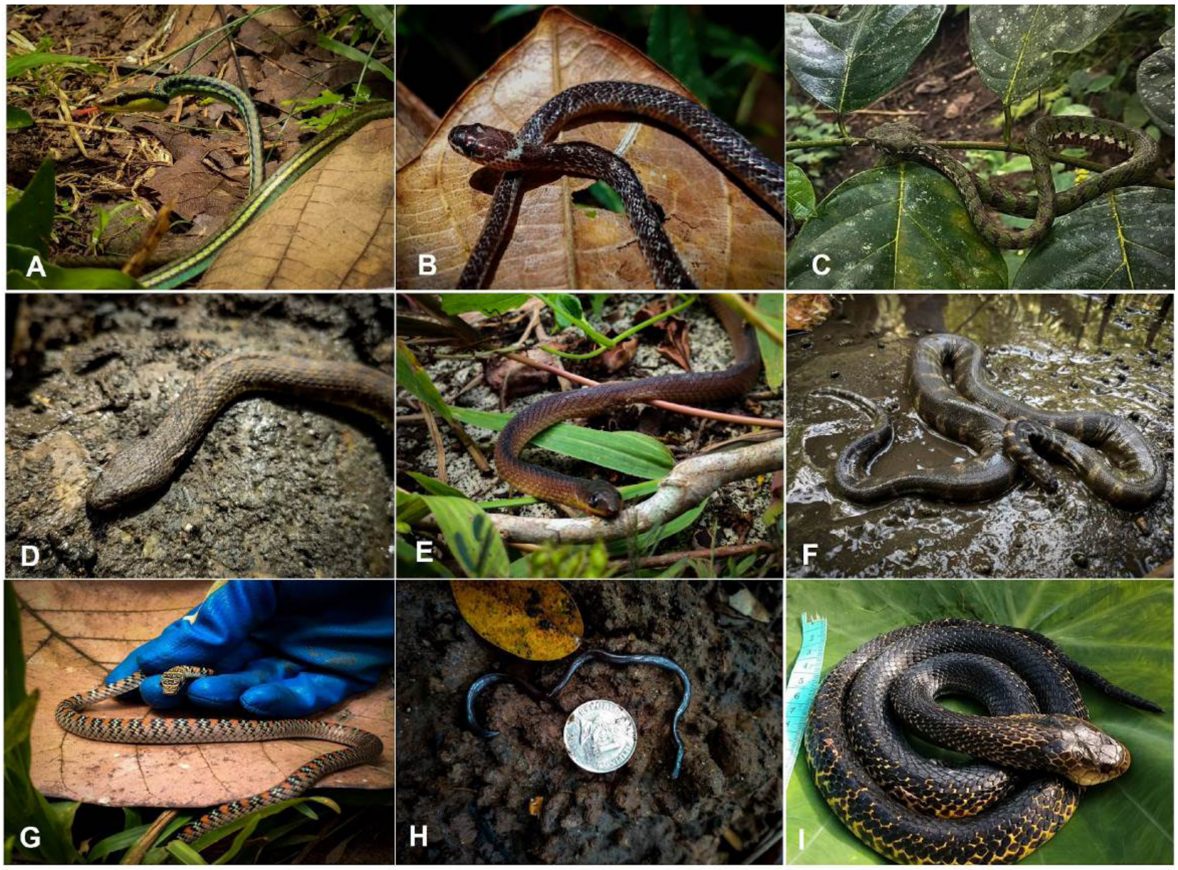

Figure 6 Recorded snake species in the Satoyama-Satoumi Landscape and Seascape of Butuan City, Agusan del Norte, Philippines

Notes: A = *Dendrelaphis marenae*; B = *Lycodon capucinus*; C = *Trimeresurus flavomaculatus*; D = *Cerberus schneiderii*; E = *Oxyrhabdium modestum*; F = *Acrochordus granulatus*; G = *Chrysopelea paradisi variabilis*; H = *Indotyphlops braminus*; and I = *Naja samarensis*.

Among amphibians, Dicroglossidae was the most represented family with six species, followed by Microhylidae with three species. The remaining families were represented by one species each: Bufonidae, Ceratobatrachidae, Megophryidae, Ranidae, and Rhacophoridae. Meanwhile, family Scincidae had the highest number of species (7 species) for reptiles, followed by Gekkonidae and Colubridae with five species each, and Agamidae with four species. The remaining reptile families were represented by one species each, including Acrochordidae, Elapidae, Homalopsidae, Lamprophiidae, Pythonidae, Typhlopidae, Varanidae, Viperidae, and Geoemydidae.

The recorded 43 amphibian and reptile species already represented a significant contribution to the understanding of herpetofaunal diversity within the Satoyama-Satoumi landscape-seascape mosaic of Butuan City.

Earlier studies by Solania *et al.* (2020) and Sanguila *et al.* (2021) in Butuan City documented a considerable number of species and provided important information on habitat associations. Building on these works, the present study not only adds to the known herpetofaunal diversity of Mindanao but also highlights the ecological connectivity between terrestrial Satoyama landscapes and adjacent Satoumi seascapes.

This integrative perspective supports ongoing efforts to more comprehensively document herpetological diversity in the southern Philippines (Brown *et al.* 2013; Sanguila *et al.* 2016; Plaza *et al.* 2025; Sanguila *et al.* 2026) and offers the first assessment of amphibians and reptiles within this coupled landscape–seascape system in Butuan City.

Endemism, Invasive Species, and Conservation Status

Conservation categories of the herpetofaunal species recorded in Satoyama-Satoumi sites in Butuan City was carried out following the International Union for Conservation of Nature (IUCN) Red List (2025–2), while national protection status was based on Department of Environment and Natural Resources-Administrative Order 2019–09 (DAO 2019–09) (Table 1). A separate

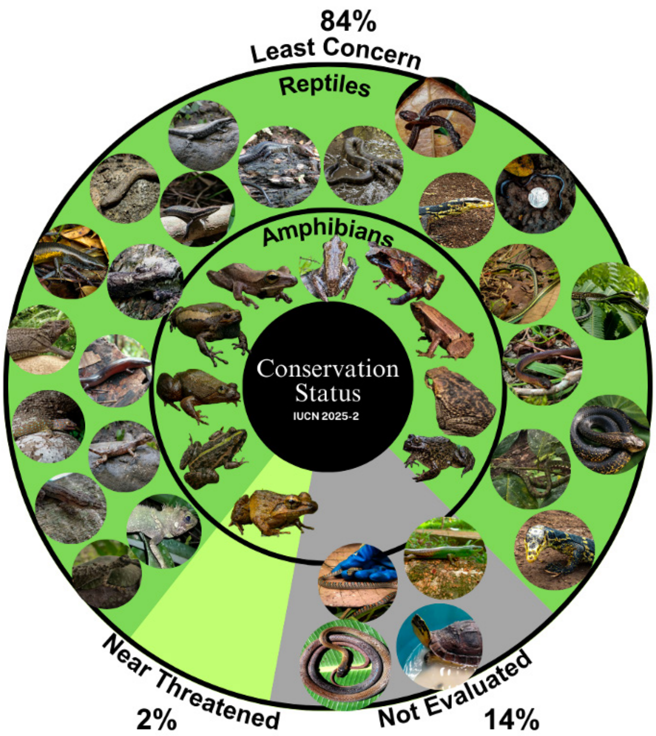

Figure 7 Global conservation status of the 43 herpetofaunal species recorded across the Satoyama-Satoumi gradient of Butuan City, based on the IUCN Red List (version 2025–2)
Notes: Percentages represent the proportion of species within each category.
Photographs correspond to species observed during field surveys.

visual synthesis of global conservation profile of herpetofauna species in which species are arranged around the circular plot based on their categories (Fig. 7).

Herpetofaunal assemblage of the Satoyama-Satoumi gradient comprised 43 species, of which 24 species (57%) were Philippine endemics, and more than 30% (n = 13) were restricted to the Mindanao faunal region (Brown *et al.* 2013; Sanguila *et al.* 2016). These included nine anurans (*Platymantis dorsalis, Fejervarya vittigera, Limnonectes leytensis, L. magnus, Occidozyga laevis, Pelobatrachus stejnegeri, Kaloula picta, Kalophrynus sinensis,* and *Hylarana grandocula*), 11 lizards (*Draco bimaculatus, Gonocephalus cf. interruptus, Hydrosaurus pustulatus, Cyrtodactylus agusanensis, Ptychozoon intermedium, Brachymeles orientalis, Eutropis multicarinata Lamprolepis smaragdina philippinica, Pinoyscincus abdictus abdictus, Tropidophorus misaminius,* and *Varanus cumingi*), three snakes (*Naja samarensis, Oxyrhabdium modestum,* and *Trimeresurus flavomaculatus*), and one turtle (*Cuora philippinensis*). Notably, 13 species recorded in the study area were restricted to the Mindanao faunal region, including *L. magnus, P. stejnegeri, K. sinensis, H. grandocula, D. bimaculatus, C. agusanensis, P. intermedium, B. orientalis, P. abdictus abdictus, T. misaminius, V. cumingi, N. samarensis,* and *O. modestum*.

The assemblage in the Satoyama and Satoumi is largely composed of lowland herpetofauna typically associated with forest habitats but capable of persisting in secondary growth and agroecosystems under moderate disturbance (Brown & Diesmos, 2002; Sanguila *et al.* 2016; Sanguila *et al.* 2021; Plaza *et al.* 2025). Although habitat modification is increasing, a high number of endemic and geographically restricted species continue to persist in agricultural and semi-disturbed environments. The persistence of endemic and range-restricted species across the present sampling sites further underscores the ecological importance of agroforest landscapes and secondary growth habitats within the Satoyama–Satoumi continuum as critical refugia.

This study recorded a higher number of island-endemic species, which corresponds to the findings of Wong *et al.* (2021) on Borneo Island, Malaysia, who reported a total of 21 amphibian and reptile species. Similarly, Milto (2025) recorded only 22 Javan endemic amphibians and reptiles in Gunung Gede Pangrango National Park, West Java, Indonesia.

This pattern is expected, as the areas in Malaysia and Indonesia are less disturbed compared to the study site. Moreover, a study from northern Luzon Island in the Philippines reported a higher number of endemic species, with 25 species being endemic to the island (Cruz *et al.* 2021). This suggests that, despite the study area in Mindanao being a human-modified landscape, it still harbors island-endemic species. Their presence across the sampling sites underscores the ecological importance of both the agroforest landscapes of Tungao and the coastal–mangrove systems of Masao as refugia for geographically restricted taxa.

In contrast, three anuran species (*R. marina*, *K. pulchra*, and *H. rugulosus*) are recognized as Invasive Alien Species (IAS) in the Philippines. *R. marina*, native to Central and South America, was likely introduced as a biocontrol agent during the expansion of sugarcane plantations and the industrial period in the country (Diesmos *et al.* 2006; Sanguila *et al.* 2016). *H. rugulosus*, native to China and Southeast Asia, was first recorded in Laguna Province in the late 1990s (Diesmos *et al.* 2006). Since this initial detection, the species has continued to spread across various Philippine islands (Brown *et al.* 2012). *K. pulchra* was probably accidentally introduced through agricultural and horticultural products and is now widely distributed nationwide (Diesmos *et al.* 2006, 2015; Diesmos & Brown 2011; Sy 2014; Sanguila *et al.* 2016). All three species are commonly observed near human settlements, agricultural areas, and irrigation systems (Sanguila *et al.* 2016; McLeod *et al.* 2011). Their frequent occurrence in disturbed or human-modified habitats reflects their well-documented ability to colonize anthropogenic environments and thrive under altered ecological conditions.

Rhinella marina is a highly generalist feeder, consuming a wide and diverse array of food items, including insects, plant material, inorganic matter, and even reptile-like species. Comprehensive examination of stomach contents revealed numerous unidentifiable insect fragments, further highlighting the species' opportunistic and broad dietary habits. Such feeding flexibility allows *R. marina* to exploit available resources efficiently, which likely contributes to its successful establishment across a variety of habitats. These observations suggest that *R. marina* may pose a substantial threat to native wildlife, not only by competing for prey resources but also by potentially altering local food webs and disrupting ecosystem balance. Understanding the dietary preferences and ecological role of this invasive amphibian is therefore critical for developing effective management strategies, mitigating its impacts on native species, and maintaining ecosystem integrity (Torralba *et al.* 2022).

Moreover, invasive amphibians such as *R. marina*, *Kaloula pulchra*, and *H. rugulosus* have been reported to harbor a range of parasites that pose significant ecological risks by facilitating transmission to other animals. This adds another layer of threat to native wildlife and emphasizes the potential for zoonotic transmission to both wildlife and humans. Collectively, these findings highlight the urgent need for proactive, community-based management strategies aimed at controlling invasive anuran populations, monitoring their ecological impacts, and preventing the spread of parasites in natural and human-modified environments (Torralba *et al.* 2023).

The study assessed the conservation status and population trends of herpetofaunal species recorded across Butuan City's landscape and seascape based on the IUCN Red List of Threatened Species (version 2025–2). Most species (84%) were classified as Least Concern (LC), as illustrated in Figure 7, while a smaller proportion falls under higher-risk categories, including Near Threatened (2%). Notably, 14% of the species remain Not Evaluated (NE), reflecting gaps in ecological and population data.

Among amphibians, 13 of 14 species are categorized as Least Concern, with only *Limnonectes magnus* listed as Near Threatened. Of the 29 reptile species, 19 are classified as Least Concern, five as Not Evaluated, and one (*Gonocephalus* sp.) remains unknown due to taxonomic uncertainty. Despite the predominance of Least Concern species, population trends indicated potential conservation concerns: six amphibians (*P. dorsalis, F. vittigera, L. leytensis, L. magnus, H. rugulosus,* and *O. laevis*) and five reptiles (*A. granulata, H. pustulatus, P. intermedium, N. samarensis,* and *T. flavomaculatus*) exhibited declining population trends. Additionally, several species (three amphibians and ten reptiles) have unknown population trends, underscoring the lack of long-term monitoring data.

Complementing global assessments, national conservation status based on DENR Administrative Order No. 2019–09 classifies 12 species (e.g., *L. magnus, Pelobatrachus stejnegeri, Gekko gecko, Hydrosaurus pustulatus, Varanus cumingi,* and *Naja samarensis*) as Other Threatened Species

(OTS), while the remaining taxa are designated as Other Wildlife Species (OWS) or no local conservation status.

These discrepancies between global and national assessments highlight the importance of incorporating local-scale data, such as abundance, habitat requirements, and population trends, for more accurate conservation evaluations (Plaza *et al*. 2025). Despite increasing research efforts, ecological studies still comprise only a small proportion (12%) of Philippine herpetological literature (Meneses *et al*. 2024). The continued lack of baseline data on distribution, abundance, and population dynamics remains a major constraint in assessing the true conservation status of many species (Plaza *et al*. 2025).

Herpetological research in the Philippines underscores the country's remarkable amphibian and reptile diversity, high levels of endemism, and the critical need to evaluate conservation status. Surveys conducted in the Rajah Sikatuna Protected Landscape, in Bohol Island in central Philippines, recorded 54 species, including 24 Philippine endemics and several threatened taxa, highlighting the urgency of protecting biodiversity-rich areas (Aureo 2025). Likewise, studies in the Kapatagan Watershed and southern Mindanao revealed substantial endemism, the presence of vulnerable species, and gaps in data on threats and distribution, emphasizing the importance of incorporating conservation assessments into research and management priorities (Villantes *et al*. 2025; Abdullah *et al*. 2023). Reassessments in the Cordillera Mountain Range of Luzon further demonstrated that incomplete distributional data can lead to under- or overestimation of threat levels, potentially compromising conservation planning (Brown *et al*. 2012). Collectively, these studies indicate that systematic conservation evaluations, particularly IUCN Red List assessments, are essential for identifying at-risk species, informing management strategies, and guiding policy development throughout the Philippine archipelago (Aureo 2025).

Diversity Indices

The results revealed clear differences in amphibian and reptile community structure between the two sampling sites, i.e., Barangay Masao (Satoumi seascape) and Barangay Tungao (Satoyama landscape), as reflected in species richness, abundance, diversity, dominance, and evenness (Table 2).

Barangay Tungao exhibited substantially higher species richness (S = 36) compared to Barangay Masao (S = 19), indicating a more diverse assemblage of amphibians and reptiles in the terrestrial landscape. This pattern is further supported by the higher Shannon diversity index in Tungao (H' = 2.57) relative to Masao (H' = 1.94), suggesting not only greater species numbers but also a more complex and structured community. The elevated diversity in Tungao may be attributed to the heterogeneity of habitat types typically associated with satoyama systems (e.g., mixed agricultural areas and secondary growth forest), which provide a wider range of ecological niches, microhabitats, and breeding sites, similar to the herpetological assemblage study in mixed agricultural areas and secondary growth forest of Mt. Agad-agad (Maglangit *et al*. 2022).

Across both barangays, the overall Shannon diversity index (H' = 2.43) indicated moderate to high diversity within the study area. However, when examined individually, the contrast between sites became evident. The higher Shannon index in Tungao (H' = 2.57) indicated that species are more diverse and that no single species overwhelmingly dominates the community. In contrast, the lower diversity value in Masao reflected fewer species and/or more uneven abundances, likely influenced by environmental constraints typical of satoumi systems, such as salinity, habitat specialization, and coastal dynamics, as many amphibians and reptiles are more commonly associated with terrestrial landscape ecosystems (Sanguila *et al*. 2016 2021; Plaza *et al*. 2025).

Table 2 Species richness, diversity, evenness, and dominance of anurans found in the sampling sites during the sampling period from January to February 2022 (wet season) and June to July 2022 (wet season), Butuan City, Philippines

Sampling site	Species richness (S)	Abundance (N)	Species diversity (H')	Dominance (D)	Evenness (E)
Barangay Masao	19	419	1.94	0.23	0.36
Barangay Tungao	36	549	2.57	0.12	0.35
Total	43	968	2.43	0.15	0.30

Dominance values further distinguished the two sites. Barangay Masao showed a higher dominance index (D = 0.23) compared to Tungao (D = 0.12), indicating that its herpetofaunal community was more strongly influenced by a few dominant species (e.g., *L. moodiei* and *A. granulata*), which were well adapted to estuarine, mangrove, and brackish environments (Brown *et al.* 2013; Wallach *et al.* 2015). This suggests a less balanced community structure in Masao, where certain species outcompete others under more constrained or specialized environmental conditions. Overall, the combined interpretation of these indices suggests that Barangay Tungao supports a more diverse and ecologically stable herpetofaunal community, whereas Barangay Masao is characterized by lower diversity, higher dominance, and slightly more even distribution within a limited species pool. This pattern reflects the reliance of amphibians and reptiles on suitable microclimates for key life-history strategies (Scheffers *et al.* 2013, 2014; Jins *et al.* 2022; Plaza *et al.* 2025) and points to differences in habitat quality, environmental conditions, and ecological constraints between the two barangays.

This study revealed a high overall diversity within the herpetofaunal community, characterized by a relatively rich assemblage of species with moderate variation in abundance. These findings contribute to the growing body of biodiversity assessments conducted across various ecosystems in Mindanao, which consistently demonstrate the region's exceptional levels of herpetofaunal diversity and endemism. Collectively, such studies highlight the remarkable species richness and distinctive composition of amphibian and reptile communities in Mindanao (Abdullah *et al.* 2023).

Consistent with other herpetofaunal studies in Southeast Asia, the present study further underscores the high levels of species diversity supported by tropical ecosystems in the region. For example, Kennedi *et al.* (2024) documented 142 species in Bukit Baka Bukit Raya National Park, West Kalimantan, Indonesia, including 78 amphibians and 64 reptiles, emphasizing the area's status as a biodiversity hotspot with high endemism and relatively intact habitats. In contrast, Ramli *et al.* (2024) reported 38 herpetofauna species in Gunung Belumut Amenity Forest, Peninsular Malaysia, comprising 18 amphibians and 20 reptiles. The comparatively higher diversity recorded in the present study highlights the variability of herpetofaunal richness across different landscapes. Such differences are likely influenced by variations in habitat complexity, vegetation structure, microclimatic conditions, and levels of anthropogenic disturbance.

These comparisons emphasize the pronounced spatial heterogeneity of herpetofaunal communities across Southeast Asia and reinforce the importance of comprehensive, site-specific biodiversity assessments. Understanding these patterns is essential for identifying conservation priorities, mitigating habitat fragmentation, and preserving the ecological integrity of amphibian and reptile populations, which are widely recognized as sensitive indicators of environmental change. Accordingly, effective habitat management strategies that incorporate species-specific ecological requirements, along with the establishment and maintenance of habitat connectivity corridors within Satoyama-Satoumi human-modified landscapes in Butuan City, Philippines, are crucial. Furthermore, sustained long-term monitoring and research on resource availability, anthropogenic pressures, and population trends are necessary to ensure the continued stability and resilience of these faunal communities (Pastor *et al.* 2024).

Microhabitat Use of Amphibians and Reptiles

A total of 43 herpetofaunal species exhibited distinct microhabitat associations across the Satoyama (Tungao) and Satoumi (Masao) landscape-seascape gradient. Amphibians and reptiles occupied a range of environments, from arboreal vegetation and forest floors to swampy areas, mangroves, and human-modified habitats, reflecting both habitat heterogeneity and varying degrees of ecological tolerance among species. The summary of results is shown in Table 3.

Table 3 Microhabitats types of collected herpetofauna in Barangay Masao and Barangay Tungao, Agusan del Norte, Philippines

Species name	Microhabitat type	Microhabitat description
Amphibians		
R. marina	II and III	Residential road, nearby water system, rice field, grasslands
F. vittigera	II and III	Ground cover with grasslands, shrublands, ponds, creeks, rivers, forest floor, rice fields, drainage alongside to the mangrove
H. rugulosus	II and III	Rice fields, river near human settlements, along highways, forest floor adjacent to water bodies
L. leytensis	II	Swampy areas
L. magnus	II and III	Mangroves, embankment of fishponds, roads near man-made ponds, grasslands adjacent to creeks, rice fields, forest swampy areas, boulders of rocks near water system
O. laevis	II	Puddles, swampy areas
P. stejnegeri	III	Forest floor, Thick leaf litters
K. picta	II and III	Ground covered with domestic plants and swampy areas
K. pulchra	II, and III	Rice fields, muddy areas, piles of bamboo near coastal areas
K. sinensis	II, and III	Fallen logs, rotting logs adjacent to riverine
P. grandocula	II	Rivers and water systems
P. leucomystax	I	Bird's nest axil, trunk of *Lantana Camara* trees, leaves of trees, temporary nipa huts near shrublands, grasslands nearby clear pools, leaf axils of *Musa textilis*, tree branches and saplings
Reptiles		
A. granulatus	II	Fishpond, Mangroves
D. bimaculatus	I	Trunks of Falcata and Rubber Trees
G. interruptus	I	Tree branches
H. pustulatus	I and II	Shrublands and tree branches adjacent to the river, rock crevices
C. agusanensis	III	Rotting logs
G. gecko	I	Tree Trunks, mangrove palm, tree branches, walls and ceilings in rice field temporary huts, electric post
G. mutilata	I	Walls and ceilings of temporary huts
H. frenatus	I and III	Temporary huts and, tree holes and trunk of mangroves, walls and ceilings, electric post, ground cover with grasslands
P. intermedium	I	Coconut trunk
B. orientalis	III	Coconut husk, ground cover with leaf litters
E. multifasciata *E. multicarinata*	I and III III	Dry leaves of cogon grass, grasslands nearby fishponds and mangroves, gardens, trunks of coconut trees,
L. smaragdina philippinica	I	Trunks and tree barks of coconut, gmelina, falcata, papaya, caimito, mango, and rubber.
P. abdictus abdictus	III	Rock crevices in stream bed
T. misaminius	II and III	Rock crevices in stream bed, rotting logs
V. Cumingi	II and III	Mangrove's shrubland, public cemetery, grasslands adjacent to river, forest grasslands
C. paradisi	I, III	Man-made habitation near rice field, coconut branches
C. erythrurus	II and III	Forest floor, nipa hut and coconut plantations, grassland adjacent to the river
D. marenae	I	Branches of ferns, tree saplings
L. capucinus	III	Tree buttress of falcata
N. samarensis	III	Forest floor, rice field and plantation near human settlement
C. rynchops	II	Fishponds, mangrove
M. reticulatus	II and III	Residential grasslands, river
R. braminus	III	Rotten logs, forest floor,
T. flavomaculatus	I	Tree saplings
C. philipinensis	II	Muddy areas of forest, grasslands adjacent to clear stagnant waters, abandoned sinkholes

Microhabitat Use by Amphibians

In the Satoyama landscape and Satoumi seascape, amphibian species occupied either single or overlapping microhabitats, reflecting species-specific preferences for microclimatic conditions that support essential life-history functions (Plaza *et al.* 2015). Most amphibian species (7 species) were recorded in multiple overlapping microhabitats (Microhabitats II and II), including the generalist and disturbance-tolerant species such as *R. marina*, *F. vittigera,* and *H. rugulosus*, which occurred along residential roads, rice fields, grasslands, drainage canals, creeks, and riverbanks. Their occurrence in both natural and human-modified habitats is consistent with previous reports that cosmopolitan anurans readily exploit anthropogenic landscapes (Diesmos *et al.* 2006; Grismer *et al.* 2010). Other species also occupied multiple microhabitats but showed strong affinity for swampy or semi-aquatic environments (Microhabitat II), including *L. leytensis*, *L. magnus*, *O. laevis*, and *P. grandocula*, which were frequently recorded in forest swamps, puddles, creek margins, and riverine habitats. These habitats provide essential breeding and foraging areas, particularly for water-dependent anurans (Scheffers *et al.* 2013). Understanding patterns of faunal movement within habitats is key to informing ecological assessments and designing targeted conservation strategies (Sawaki *et al.* 2025).

Forest-dependent species occupied a single microhabitat (Microhabitat III). Although encountered less frequently, these species exhibited a clear preference for undisturbed forest floors with deep leaf litter. *P. stejnegeri*, a Mindanao endemic, was restricted to deep litter layers typical of low-disturbance forest microhabitats. Similarly, microhylid such as *K. sinensis* was associated with rotting logs adjacent to riverine habitats. Only one amphibian species, *P. leucomystax*, primarily occupied arboreal microhabitats (Microhabitat I). It was observed on tree trunks, leaf axils, saplings, and temporary huts, consistent with its well-documented arboreal and synanthropic behavior. Its occurrence in both natural and semi-urban environments reflects its exceptional ecological plasticity. Overall, amphibian microhabitat use ranged from forest-dependent endemic species in Tungao to disturbance-tolerant species in Masao, illustrating the influence of land-use intensity and habitat modification on community composition.

Microhabitat Use by Reptiles

Reptiles exhibited broader microhabitat partitioning, with notable representation in arboreal (I) and terrestrial (II) habitats and limited but important use of aquatic or mangrove-associated areas (III). Arboreal specialists (Microhabitat I) dominated the reptile assemblage. Species such as *D. bimaculatus* and *G. interruptus* were frequently observed on tree trunks and branches in agroforest zones, consistent with reports that agamids rely on vertical forest stratification for foraging and thermoregulation (McGuire & Alcala 2000). *G. gecko* and *G. mutilata* showed high synanthropy, often occurring on the walls and ceilings of temporary huts, electric posts, and mangrove palms, highlighting their ability to thrive in human-dominated landscapes. *P. intermedium* and *L. smaragdina philippinica* commonly preferred trunks and tree barks of agroecosystem areas.

Reptiles utilizing terrestrial microhabitats (II) included species such as *H. pustulatus*, which occupied rock crevices, shrubs, and vegetated riverbanks. Its frequent association with riparian zones highlights its semi-aquatic tendencies, where access to both land and water is critical for thermoregulation, escape behavior, and foraging (Sanguila *et al.* 2016; Sanguila *et al.* 2021).

In contrast, the aquatic snake *A. granulatus* was observed in mangroves and along fishpond embankments, reflecting its obligate aquatic ecology and dependence on brackish water systems (Supsup *et al.* 2016). Forest-floor specialists, such as *C. agusanensis*, were primarily detected in Microhabitat III, particularly within rotting logs and decaying wood. These microhabitats provided stable humidity, shelter from predators, and abundant invertebrate prey, making them essential for moisture-dependent reptile species (Huey *et al.* 2009; Slavenko *et al.* 2022). In addition to these habitat specialists, several reptile species exhibited use of multiple, overlapping microhabitats, including *E. multifasciata*, *T. misaminius*, *V. cumingi*, *C. erythrurus*, and *M. reticulatus*. The occurrence of these generalist species across multiple microhabitats underscores the role of habitat heterogeneity in maintaining reptile diversity within the landscape (Sanguila *et al.* 2021; Supsup *et al.* 2022).

Overall, these findings emphasized that habitat complexity and microhabitat diversity are critical drivers of amphibian and reptile community structure, and that alterations to vegetation structure, hydrological systems, and substrate availability may have significant consequences for species persistence (Alcala *et al.* 2012; Brown *et al.* 2012; Sanguila *et al.* 2016, 2021; Supsup *et al.* 2022; Plaza *et al.* 2025). Endemic and Mindanao-restricted species were particularly associated with specialized microhabitats that are highly vulnerable to disturbance, underscoring their sensitivity to environmental change and habitat degradation. The continued expansion of agriculture, aquaculture, and settlement development, coupled with the increasing presence of invasive species, poses persistent and compounding threats to the herpetofaunal communities (Abdullah *et al.* 2023).

Collectively, reptile microhabitat use reflects the interplay between vertical stratification, proximity to water, and availability of structural refugia. Arboreal habitats were the most heavily used, in contrast with amphibians, which relied predominantly on terrestrial and aquatic substrates. Reptile abundance tends to decline with increasing habitat modification, reflecting the vulnerability of these species to environmental disturbances. Structural habitat features, such as water availability and dense vegetation cover, were positively associated with reptile diversity and abundance, likely because they provide essential resources for foraging, thermoregulation, and shelter. Conversely, disturbance factors, including reduced habitat area and closer proximity to human settlements, negatively affected reptile communities, increasing their exposure to predation, habitat degradation, and human-wildlife interactions. These patterns underscore the critical role of maintaining habitat complexity and minimizing anthropogenic pressures to sustain healthy reptile populations in human-modified landscapes (Janiawati *et al.* 2016).

CONCLUSION

This study provides a baseline assessment of herpetofaunal diversity in Butuan City, Philippines, documenting 43 amphibian and reptile species across the Satoyama-Satoumi landscape-seascape gradient. Higher species richness and endemicity were observed in Barangay Tungao, reflecting its relatively intact agroforest and riparian habitats, while Barangay Masao supported fewer species and more disturbance-tolerant and invasive taxa. Although most species were classified as Least Concern under the IUCN Red List, the presence of a Near Threatened species, together with 11 nationally recognized Other Threatened Species (OTS) under DAO 2019-09 highlights the ecological significance of these areas. Endemic and Mindanao-restricted species were particularly associated with microhabitats vulnerable to habitat alteration, emphasizing the sensitivity of these taxa to environmental change. The continued expansion of agriculture, aquaculture, settlement development, and the presence of invasive species pose persistent threats to the herpetofaunal communities of both barangays. Strengthening habitat protection, regulating extractive and destructive practices, and implementing sustained monitoring are therefore essential. Conservation measures should prioritize habitat-quality maintenance in Tungao and mitigation of anthropogenic pressures in Masao, alongside community-based awareness efforts in alignment with the Satoyama–Satoumi socio-ecological framework. Overall, this baseline assessment provides critical information for local biodiversity planning and highlights the need for long-term ecological monitoring to safeguard the remaining herpetofaunal diversity of Butuan City, Philippines.

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