

Species composition and conservation of amphibians in Central Panay Mountain Range, Antique, Philippines

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Abstract. Flores GMA, Torres AG, Flores ABA, Jakosalem PGC, Guihawan JQ, Roa-Quiaoit HA. 2024. Species composition and conservation of amphibians in Central Panay Mountain Range, Antique, Philippines. *Biodiversitas* 25: 1797-1808. Assessing amphibian species composition and conservation status in Central Panay Mountain Range (CPMR), the largest contiguous forest in West Visayas in central Philippines, provides relevant and updated information on the status and conservation needs of the amphibians. Opportunistic, visual encounter and acoustic surveys were employed across diverse habitats-lowland and lower montane forests, streams, and grasslands. A total of 11 amphibian species from six families were documented, with notable findings including endemic species such as Rough-backed forest frog *Platymantis corrugatus* Duméril 1853, Dumeril's wrinkled ground frog *Platymantis dorsalis* Duméril 1853, and Philippine narrow-mouth toad *Kaloula conjuncta negrosensis* Taylor 1922, as well as threatened species Panay forest frog *Platymantis panayensis* Brown, Brown and Alcalá 1997, which is endemic to Panay Island. The *P. dorsalis* emerged as the most abundant, with 127 individuals recorded. Furthermore, two new distribution records of amphibians, narrow-mouth toad *Kaloula* sp. and panther flying frog *Rhacophorus pardalis* Günther 1858 were identified, potentially representing previously undocumented species endemic to the Philippines. The survey also revealed local threats posing significant risks to amphibian populations in the area. Several conservation measures have been proposed to protect amphibians and their habitats within CPMR. Given the area's rich biodiversity and ecological integrity, efforts are currently being implemented to establish CPMR as a nationally protected area, and this study contributes to this initiative by providing baseline data on amphibian diversity, underscoring the role of amphibians as ecological indicators of ecosystem health.

Keywords: Amphibian diversity, conservation measures, endemic, local threats, West Visayas

INTRODUCTION

Amphibians are one of the most threatened taxa in the world, as shown by their rapid population decline. Their sensitivity to ecological changes makes them good biological indicators of ecosystem health (Hopkins 2007; Saber et al. 2017). As supported by the IUCN (2023b), 41% of the world's amphibians are threatened with extinction. Amphibians show high sensitivity to the effects of forest degradation and fragmentation due to the following reasons: spot fidelity, inadequate dispersion skill, and acceptable habitat class tolerance (Pittman et al. 2014) since more than 80% of the amphibian population is forest-dependent (Diesmos 2008). Global climate change is identified as one of the main reasons for the amphibian population decline as it alters amphibian habitats, influences food availability, and modifies pathogen-host dynamics, among others (Catenazzi 2015; Duan et al. 2016; Pabijan et al. 2020). Invasive alien species (IAS) and over-exploitation are also known causes of amphibian population declines (Stuart et al. 2004).

Amphibians are characterized by a biphasic cycle, which undergoes metamorphosis with aquatic larvae and

terrestrial adults (Flores et al. 2023). They also exhibit variations in morphology that correspond to different species. The order Anura, the largest order of amphibians, has more than 4500 known species; this comprises frogs and toads that are grouped into approximately thirty families (Catenazzi 2015). Adult anurans are tailless amphibians and are ectothermic, or they rely on their external environment for their temperature and have semi-permeable skin, making them highly vulnerable to environmental changes, which makes them the most successful indicators for ecosystem health (Sumanasekara et al. 2015). Due to their bi-phasic life cycle, limited dispersal abilities, and sensitivity to environmental changes brought about by habitat fragmentation, pollution, climate change, and emerging infectious diseases, they are considered good indicators for habitat quality (Dela Torre and Nuneza 2021). Apart from this, anurans constitute an important part of the food web as they act as predator and prey. Predators significantly regulate insect populations and other small invertebrates, including pests (Hocking and Babbitt 2014). At the same time, prey species serve as a crucial diet for many predators, such as reptiles, mammals (Egeter et al. 2015), and birds (Paluh et al. 2015). Thus,

frogs contribute significantly to the ecosystem's balance (Saber et al. 2017).

Anurans are widely distributed across numerous biogeographical land areas, with the highest diversity in tropical regions (Pyron 2014). The Philippines, with 7,641 islands, is home to 116 species of amphibians (ACNA 2015; NAMRIA 2017), of which 85% are endemic to the country, one of the world's highest records of amphibian endemism (Diesmos et al. 2015). Panay Island, located in the central part of the Philippines, is one of the world's biodiversity hotspots. The Central Panay Mountain Range (CPMR) is the largest forest area in West Visayas. It contains the most threatened endemic species in Panay and West Visayas (Reintar et al. 2022). The most recent amphibian survey in CPMR was conducted at least six years ago by Gaulke et al. (2003), Reintar et al. (2016, unpublished), Bess (2016, unpublished data), and Fabunan (2016, unpublished data); hence, there is a need to conduct an additional survey that would provide an update on the current status, diversity, and population of amphibian species which the local community and researchers will use for future studies and biological monitoring. These data will provide the necessary information to make informed and appropriate conservation management decisions toward establishing CPMR as a protected area. Therefore, this study provides data on amphibian species composition and conservation needs in different habitat types.

MATERIALS AND METHODS

Study area

The Central Panay Mountain Range is in Antique, Aklan, Capiz, and Iloilo provinces. It is the largest forest block in Panay Island and probably that of the West

Visayas region. Most remaining forests are classified as montane forests (over 1,000 meters above sea level/masl). The remaining lowland forests are mostly restricted to the steeper gullies in the central and northern sections of CPMR. Located on the southern tip of CPMR and adjacent to Sibalom Natural Park (SNP) is the San Remigio Municipality. The terrain is hilly, particularly in the upland Barangays. Large tracts of forests still exist in the area, from 800 to 1,100 masl. Forest types include lowland to lower montane forests with areas of forest over limestone (karst), thus the presence of cave systems, but mostly forest over soil ecosystem type was found in the area. Specific barangays identified within the sampling sites are Barangay Aningalan, Barangay Osorio Dos, and Barangay Bulan-Bulan. Habitat types such as lowland forests, lower montane forests, streams, and grassland were surveyed (Figure 1). The habitat types chosen for sampling were determined by the presence of existing and accessible streams and forest paths, facilitating the establishment of transects to mitigate negative impacts by refraining from creating new trails. Furthermore, careful consideration was given to ensure the representation of each habitat type in the sampling area within the sampling framework.

Site classification

Four habitat types were surveyed: lowland forest, lower montane forest, stream, and grassland (Figure 2). Lowland forest elevation ranged from 800-990 masl, and beyond that begins the lower montane forest. Overall, the vegetation was evergreen, with moderate to dense canopy cover and trees ranging from 10 to 40 m in height. Stream habitat is defined as the water channel plus its riparian area. Grass species, herbaceous plants, and scattered trees dominated grasslands (Figure 2).

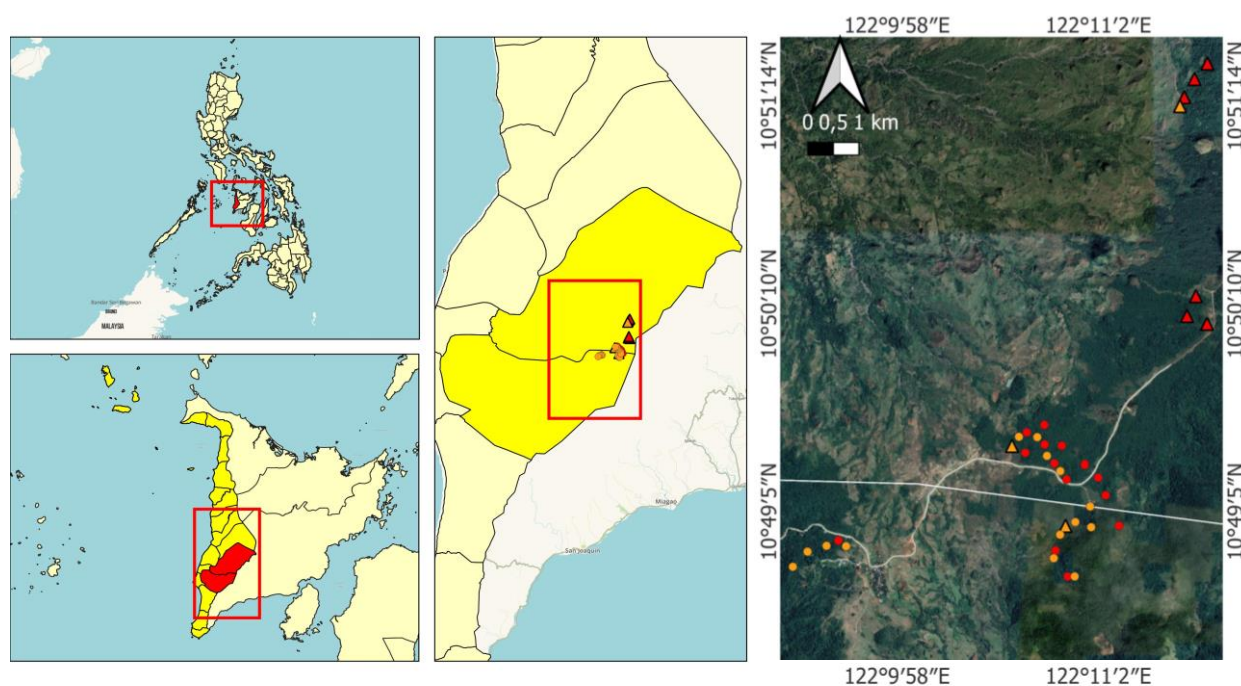


Figure 1. Map of Central Panay Mountain Range, showing the location of sampling sites in San Remigio, Philippines. ▲: Lower montane forest, ▲: Grassland, ●: Stream, ●: Lowland forest

Sampling procedure

Nocturnal surveys were conducted from 20 to 30 July 2023, using visual encounter survey (VES), opportunistic survey, and acoustic monitoring from 18:00 to 21:00 local time when amphibians were active (Rödel and Ernst 2004; Diesmos 2008; Heyer et al. 2014). Acoustic monitoring was carried out manually without the use of audio recording equipment or digital analysis tools. A 100×10 m strip transect at 100 m intervals was established to avoid sampling bias (Diesmos 2008), and all of the transect lines were marked using neon-colored ribbons based on the transect number or point at each habitat. The targeted sampling effort, however, was not reached due to unfavorable weather experiences, which limited the fieldwork for three days. Existing local threats were determined and noted during the survey.

Processing and species identification

Each amphibian species encountered at each transect was captured and placed in a clean polyethylene plastic bag. The collected specimens were processed in a field station considering fundamental morphometric measurements such as snout-vent length (SVL) and weight using a Vernier caliper and Pesola scale, respectively. Recorded amphibians were photographed in their natural habitat and were released afterward. Photographic field guides and journal articles by Alcala and Brown (1998), Ferner et al. (2000), Gaulke (2011), and Diesmos et al. (2015) were used as references for the identification. A local herpetologist confirmed the species identification of each amphibian. Further, the conservation status of each amphibian species was assessed using the International Union for Conservation of Nature red list web interface

(IUCN 2023a) and the Department of Environment and Natural Resources Administrative Order 2019-09 (DENR 2019).

Data analysis

Species diversity in different habitats was measured using the Shannon-Wiener Diversity Index (H'), which considers the number of species in an area and their evenness. The Paleontological Statistics (PAST v4.03) software was used to calculate the diversity indices of each habitat. The Evenness Index (E) was also computed to elucidate the variation sizes among species within a particular community, aiming to quantify the level of uniformity in species abundances offering valuable insights into the structural coherence and functional equilibrium of ecological communities.

RESULTS AND DISCUSSION

A total of 33 strip transects at 100 meters (m) each were surveyed, where 13 transects were in the lowland forests, six in lower montane forests, 11 in stream habitats, and three in grasslands. The total survey effort in searching for these organisms amounted to 188 man-hours, distributed across various habitats as follows: 109 man-hours in lowland forests, 26 man-hours in lower montane forests, 35 man-hours in streams, and 18 man-hours in grasslands. This effort was spread for eight nights and eight days, with varying sampling durations allocated to each specific sampling area.



Figure 2. Four different habitats: A. Lowland forest; B. Lower montane forest; C. Stream habitat; D. Grassland habitat

Species abundance

A total of 11 species (249 individuals) of frogs were recorded under six families-Bufonidae (*Rhinella marina* Linnaeus 1758), Ceratobatrachidae (*Platymantis corrugatus* Duméril 1853, *Platymantis dorsalis* Duméril 1853, *Platymantis cf. dorsalis*, and *Platymantis panayensis* Brown, Brown and Alcala 1997), Dicroglossidae (*Occidozyga laevis* Günther 1858), Microhylidae (*Kaloula conjuncta negrosensis* Taylor 1922 and *Kaloula sp.*), Ranidae (*Hylarana erythraea* Schlegel 1837), and Rhacophoridae (*Polypedates leucomystax* Gravenhorst 1829 and *Rhacophorus pardalis* Günther 1858). The ground frogs (Ceratobatrachidae) family was well represented with four recorded species and also had the highest abundance, followed by narrow-mouth frogs (Microhylidae) and tree frogs (Rhacophoridae) with two species each. The most abundant amphibian species was the *P. dorsalis*, with 127 captured individuals and an abundance score of 51.00%, followed by *O. laevis*, with 36 captured individuals and an abundance score of 14.46%, and the *P. corrugatus*, with 35 captured individuals and an abundance score of 14.06%. The complete list of species recorded is shown in Table 1.

Amphibians were found in all types of habitats, occurring highest in the lowland forest with 172 captures representing nine species, followed by lower montane forests with 17 captures representing five species, grasslands with 12 captures representing four species, and stream habitats with 16 captures representing only one species. The *P. dorsalis* was the most abundant species recorded in lowland and lower montane forests, with 91 individuals or 52.91% and eight individuals or 47.06%, respectively. The second most abundant species was the *P. corrugatus* in lowland forests, with 33 individuals and a 19.19% abundance score. The *P. panayensis* and *O. laevis* were the third most abundant species in lowland forests, with 17 individuals and an abundance score of 9.88%. In contrast, only the *O. laevis* thrived and recorded, with 16 captures in stream habitats. The invasive species *R. marina* and *H. erythraea* dominated the grassy and open areas in grassland habitats. These species are considered common in residential areas and disturbed environments, according to Janiawati et al. (2015).

Although most individuals could be identified unambiguously using morphology alone, this was not always the case in some amphibian species. A few individuals of *Platymantis cf. dorsalis* were recorded in limestone areas in lowland forests, lower montane forests, and riparian areas. This species was slightly larger, the toe discs were rounder, and the fourth toe was longer than the other species in the Ceratobatrachidae family. Another species that needed to be identified due to its unique morphology was the *Kaloula sp.* Local experts in the country are still investigating the identification of this species.

Species accounts

Bufonidae

***Rhinella marina* (Linnaeus 1758).** This species (Figure 3) was recorded in lowland forest and grassland habitats in

San Remigio. Individuals captured in the forests were slightly larger than those in the grasslands. Moreover, this species has become invasive in the country, causing ecological consequences as it outcompetes native species and disrupts the food web. Due to its wide distribution range, the IUCN lists it as least concern (IUCN 2023a). The captured individuals in the study exhibited a weight range of 105 to 360 grams (g) and a snout-vent length (SVL) range of 151 to 183 millimeters (mm). Ceratobatrachidae

***Platymantis corrugatus* (Duméril 1853)** is a common forest frog species (Figure 4) in the West Visayas Region. It was mainly observed on the forest floor with about 5 to 140 mm leaf litter depths. Thirty-five individuals were recorded, 33 in lowland forests and 2 in lower montane forests. The IUCN (2023a) classifies *P. corrugatus* as Least Concern. The captured individuals in the study exhibited a weight range of 2.1 to 10.3 g and a snout-vent length (SVL) range of 28 to 48.3 mm.

***Platymantis dorsalis* (Duméril 1853).** Like *P. corrugatus*, *P. dorsalis* (Figure 5) was observed on the forest floor with a 0.5 to 140 mm leaf litter depth. This species was the most abundant, with 127 individuals recorded from lowland forests (119 individuals) and lower montane forests (eight individuals). The conservation status of this species is least concern (IUCN 2023a). The captured individuals in the study exhibited a weight range of 1.2 to 6.5 g and a snout-vent length (SVL) range of 21.4 to 39.0 mm.



Figure 3. *Rhinella marina*



Figure 4. *Platymantis corrugatus*

Table 1. Comparison of the recorded amphibian species in different habitats

Species name	Local name	Distribution	IUCN 2023	DAO 2019-09	Lowland forest	Lower montane forest	Stream	Grassland	Total
Bufonidae									
South American cane toad	<i>Wayan</i>	W	LC	NE	8	-	-	5	13
<i>Rhinella marina</i> (Linnaeus 1758) *					(3.96%)			(41.67%)	(5.22%)
Ceratobatrachidae									
Rough-backed forest frog	<i>Pangka sa bukid</i>	PE	LC	NE	33	2	-	-	35
<i>Platymantis corrugatus</i> (Duméril 1853)					(16.34%)	(10.53%)			(14.06%)
Dumeril's wrinkled ground frog	<i>Pangka sa bukid</i>	PE	LC	NE	119	8	-	-	127
<i>Platymantis dorsalis</i> (Duméril 1853)					(58.91%)	(42.11%)			(51.00%)
Panay forest frog	<i>Pangka sa bukid</i>	PIE	EN	VU	17	5	-	-	22
<i>Platymantis panayensis</i> (Brown, Brown and Alcalá 1997)					(8.42%)	(26.32%)			(8.84%)
Forest frog <i>Platymantis cf. dorsalis</i>	<i>Pangka sa bukid</i>	PE	LC	NE	3 (1.49%)	3 (15.79%)	-	-	6 (2.41%)
Dicroglossidae									
Philippine oriental frog	<i>Lupog</i>	N	LC	NE	17	-	16	3	36
<i>Occidozyga laevis</i> (Günther 1858)					(8.42%)		(100%)	(25.0%)	(14.46%)
Microhylidae									
Philippine narrow-mouth toad	<i>Manla</i>	PE	LC	NE	1	-	-	-	1
<i>Kaloula conjuncta negrosensis</i> (Peters 1863)					(0.50%)				(0.40%)
Narrow mouth toad	<i>Manla</i>	-	-	-	2	-	-	-	2
<i>Kaloula</i> sp.					(0.99%)				(0.80%)
Ranidae									
Common green frog	<i>Manwit sa humayan</i>	W	LC	NE	-	-	-	3	3
<i>Hylarana erythraea</i> (Schlegel 1837) *								(25.0%)	(1.20%)
Rhacophoridae									
Java whipping frog	<i>Manwit</i>	N	LC	NE	-	-	-	1	1
<i>Polypedates leucomystax</i> (Gravenhorst 1829)								(8.33%)	(0.40%)
Panther flying frog	<i>Manwit</i>	N	LC	NE	2	1	-	-	3
<i>Rhacophorus pardalis</i> (Günther 1858)					(0.99%)	(5.26%)			(1.20%)
Total number of individuals					202	19	16	12	249
Total number of species					9	5	1	4	11
Endemic					5	4	-	-	6
Threatened species (IUCN 2023 and DAO 2019 - 09)					1	1	-	-	1
Total man-hours spent					109	26	35	18	188

Note: Scientific names are arranged by families and are classified based on distribution (W: Widespread; PE: Philippine endemic; PIE: Panay Island endemic; N: Native). Conservation status (LC: Least Concern; EN: Endangered; VU: Vulnerable; NE: Not Evaluated) based on the IUCN (2023) and the DENR-DAO 2017-11 (DENR 2019). Asterisks (*) denote that the species are invasive alien species. Note that the number inside the parentheses refers to abundance scores, while the numbers outside are the total number of individuals recorded

***Platymantis panayensis* (Brown, Brown and Alcalá 1997).** This threatened species (Figure 6) is an arboreal frog recorded near bodies of water. A restricted species is found only in Panay Island, with individuals known to exist in the high-elevation forests of the Northwest Panay Peninsula and Central Panay Mountain Range (Diesmos et al. 2015). This study confirmed the first record of this species in the southern part of CPMR. This frog was primarily recorded in lowland forests with 17 individuals and lower montane forests with five individuals. The conservation status of this species is Endangered based on the IUCN conservation assessment criteria (IUCN 2023a) and Vulnerable based on the DENR Administrative Order 2019-09 (DENR 2019). The captured individuals in the study exhibited a weight range of 3.6 to 5.0 g and a snout-vent length (SVL) range of 30.0 to 36.0 mm.

***Platymantis cf. dorsalis* (Duméril 1853).** Three individuals were documented each on the forest floor of lowland forest and lower montane forest during the survey. They were recorded in rocky outcrops within forests near streams. The species (Figure 7) closely resembles the common *P. dorsalis*; the only difference is the slightly rounder digits and slightly longer fourth toes than the *P. dorsalis*. Some individuals had dark lines from their snout to their tympanum, a prominent feature of *P. corrugatus*. The identity of this species is still uncertain, and further identification of its morphology and ecology is needed. The conservation status of this species is Least Concern (IUCN 2023a). The captured individuals in the study exhibited a weight range of 1.9 to 6.9 g and a snout-vent length range of 26.6 to 40.8 mm.

Dicroglossidae

***Occidozyga laevis* (Günther 1858).** This species (Figure 8) was documented in stream habitats and puddles in lowland forests and grasslands. It was mostly abundant in streams within lowland forests with 17 individuals, stream habitats with 16 individuals, and muddy puddles in grasslands with three individuals. It is classified as Least Concern (IUCN 2023a). The captured individuals in the study exhibited a weight range of 1.6 to 19.4 g and a snout-vent length (SVL) range of 24.5 to 52 mm. Microhylidae

***Kaloula conjuncta negrosensis* (Peters 1863).** This species (Figure 9) is a subspecies of *K. conjuncta* in Negros and Panay. Based on the phylogenetic analysis of Blackburn et al. (2013), the monophyletic and genetic distinctiveness of each *K. conjuncta* subspecies suggests that each may permit specific status, and the conservation status will need independent assessment and classified as least concern by the IUCN (2023a). The captured individuals in the study exhibited a weight of 4.9 g and a snout-vent length (SVL) of 39.0 mm.

***Kaloula* sp. (undescribed).** This species (Figure 10) was caught settling on a small tree trunk and tree holes in a lowland forest habitat. It is different from other *Kaloula* species because of its smaller size and darker color. Two individuals were recorded. This is the first record of this species in southern CPMR. According to herpetologists in the country, this species is still under scrutiny since they firmly believe it is a unique species of *Kaloula* found only

in Panay Island. Weight: The captured individuals in the study exhibited a weight range of 3.6 to 5.0 g and a snout-vent length (SVL) range of 7.8 to 32.3 mm.



Figure 5. *Platymantis dorsalis*



Figure 6. *Platymantis panayensis*



Figure 7. *Platymantis cf. dorsalis*



Figure 8. *Occidozyga laevis*

Ranidae

***Hylarana erythraea* (Schlegel 1837).** This species (Figure 11) is an introduced species that became invasive in the Philippines. It was recorded in a grassland habitat near puddles and the other invasive alien species, *R. marina*. This species is easily identified because of its distinct white bands on its body and its noticeable tympanum. Only three individuals were recorded. It is listed as Least Concern (IUCN 2023a). The captured individuals in the study exhibited a weight range of 5.2 to 23.6 g and a snout-vent length (SVL) range of 36.0 to 60.0 mm.

***Polypedates leucomystax* (Gravenhorst 1829).** This species (Figure 12) is common and widely distributed throughout the country, occupying even disturbed habitats (Sanguila et al. 2016). One individual was recorded in a grassland habitat, settling on a fern leaf. This species is considered Least Concern (IUCN 2023a). The captured individuals in the study exhibited a weight of 3.8 g and a snout-vent length (SVL) of 43.0 mm.

***Rhacophorus pardalis* (Günther 1858).** This species (Figure 13) is widely distributed throughout the Philippines (Brown and Alcala 1994; Gaulke 2003). However, this is the first record of this species in CPMR. It has a conspicuous call above the canopy, has heavily webbed feet and fingers used for gliding, and has large pads on fingers and toes. It is considered least concern by the IUCN (2023a). The captured individuals in the study exhibited a weight of 7.1 g and a snout-vent length (SVL) of 45.7 mm.

Species endemism and conservation status

Another important component of community structure is the species distribution range since it is considered one of the major factors critical to the study of the biotic responses to environmental factors and is also correlated with extinction risk in organisms (Cooper et al. 2008; Khatiwada et al. 2019). Of the 11 species of amphibians recorded, only *P. panayensis* is endemic to Panay (9.09%), the *P. corrugatus*, *P. dorsalis*, *P. cf. dorsalis*, *K. conjuncta negrosensis*, and *Kaloula sp.* or 45.45% are Philippine endemic. The archipelagic nature of the Philippines has led to the evolution of unique species of amphibians on various islands, which led to the many species of amphibians in the country being endemic (Brown et al. 2013).



Figure 9. *Kaloula conjuncta negrosensis*



Figure 10. *Kaloula sp.*



Figure 11. *Hylarana erythraea*



Figure 12. *Polypedates leucomystax*



Figure 13. *Rhacophorus pardalis*

The *P. panayensis* has a small distribution range, only recorded in the Northwest and Central Panay. According to Whitton et al. (2012) and Duan et al. (2016), species with a small distribution range will likely be at risk as their entire range can be easily affected by threats. Hence, only *P. panayensis* is categorized as Endangered by the IUCN (2023a) and Vulnerable by the DENR (2019) out of all amphibians recorded. The presence of threatened endemic species can signify broader issues within an ecosystem. Based on Hocking and Babbitt (2014), the decline of amphibians could also cause the loss of broader ecosystem services, which have received minimal attention until now. Additional surveys in CPMR and other areas in Panay are necessary to assess the amphibian population fully, considering the endemic and threatened species. Understanding the contribution of amphibians to ecosystems is also needed, which can help prioritize and garner support for conservation measures and predict the biotic and abiotic changes associated with the potential loss of species.

Species diversity, richness, and evenness of amphibians across different habitats

The overall Shannon-Wiener diversity index is $H' = 1.547$ (Figure 14), categorized as moderately diverse following Ulfah et al. (2019) and Dharma et al. (2021). The diversity index for lowland forest is 1.139, lower montane forest is 1.399, and grassland is 0.937. Stream habitat only recorded a single species; thus, the diversity and evenness index is zero.

Across habitat types, the highest number of species recorded was in lowland forests ($n = 202$ individuals; 9 species) followed by lower montane forests ($n = 19$ individuals; 5 species), grassland ($n = 12$ individuals; 4 species), and stream ($n = 16$ individuals; 1 species).

The evenness index value can describe the stability of the community. Dharma et al. (2021) stated that the smaller the value of E or close to zero, the more unequal the distribution of organisms in a community dominated by a particular species. On the other hand, the greater the value of E or close to one, the more amphibians in the community are more likely to be evenly distributed. The overall evenness index is $E = 0.65$, categorized as unstable based on the environmental community criteria $0.50 < E < 0.75$ (Dharma et al. 2021). Lower montane forest habitat had the highest evenness value ($E = 0.87$), followed by the grassland habitat ($E = 0.67$), and lowland forest ($E = 0.52$) with the least.

Lower montane forests showed moderate diversity ($H' = 1.399$), slightly higher than the lowland forest ($H' = 1.139$), with an evenness index of $E = 0.87$, categorized as a stable community. This habitat type is suitable for many amphibians due to its diverse microhabitats. The cool and moist surroundings of lower montane forests are favorable to some of the amphibian species that require specific humidity conditions and temperature levels.

Lowland forest was the second habitat type, with a moderate diversity index value ($H' = 1.139$). Despite having the highest number in terms of abundance and species recorded, the distribution of amphibians was not evenly distributed with an evenness index value of $E = 0.52$, which is in between the distressed ($0.00 < E < 0.50$) and unstable ($0.50 < E < 0.75$) community categories. The uneven distribution of amphibian species in the lowland forests of San Remigio may be caused by the abundance of certain species, such as *P. dorsalis* ($n = 127$ individuals). Moreover, several factors such as habitat quality, climate and weather patterns, habitat alteration, species interactions, and dispersal ability of amphibian species could also influence the even distribution of amphibians (Hamer and McDonnell 2008; Griffiths et al. 2010; Trochet et al. 2016).

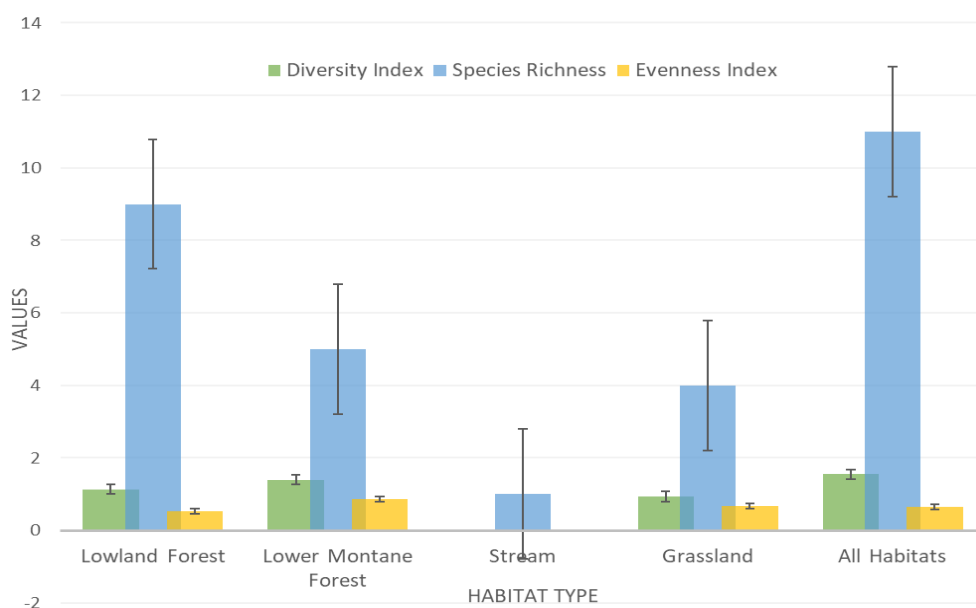


Figure 14. Diversity, richness, and evenness of amphibians in four surveyed habitats

Grasslands had the lowest diversity index value ($H' = 0.937$) and an evenness index value of $E = 0.67$. The amphibian species—*R. marina*, *H. erythraea*, *O. laevis*, and *P. leucomystax*—were recorded, and this type of habitat is favorable for these species, which have adapted to live in a more open area (IUCN 2023a). Amphibians are ectothermic with highly permeable skin, and their body temperature is influenced by their surroundings (Duellman and Trueb 1994; Kam and Chen 2000); thus, grasslands with moderate temperatures are sometimes more suitable for some amphibians.

Stream habitats are critical to the diversity and ecological health of amphibian populations. According to Keller et al. (2009), the value of stream habitats to amphibian diversity is multifaceted, encompassing ecological, reproductive, and survival components. The stream habitat had only species despite it being a suitable habitat for amphibians since the only species recorded within the stream vicinities was *O. laevis*, the only aquatic amphibian recorded.

Habitat structure is important for assessing species diversity, with more species found in physically complex habitats (Bell et al. 2012). The notable differences in amphibian assemblages in various habitat types may be attributed to differences in each species' available food resources and habitat requirements. Amphibians are susceptible to environmental changes and greatly depend on the stability and health of these ecosystems. Addressing the decline in amphibian diversity in stream habitats necessitates a multifaceted approach that includes habitat restoration, pollution control, disease management, and sustainable land-use practices.

Local existing threats

Road development

The ongoing road development from Bulan-Bulan was intended to improve road conditions and travel for locals and tourists (Figure 15). The road accesses the southern portion of CPMR, thus providing more accessible access to the forests, which serve as important habitats for the amphibian population. Road development can have various adverse effects on amphibians as it can fragment amphibian habitats, cutting off access to breeding and foraging areas as well as isolate populations and reduce genetic diversity, making amphibian populations more vulnerable to environmental changes and diseases (Andrews et al. 2004, unpublished data; Hamer et al. 2015). These effects can be particularly significant because amphibians often need to migrate between aquatic breeding habitats and terrestrial environments, and roads can create barriers and hazards for them. The construction of roads often requires the clearing of vegetation and alterations to the landscape. It can directly destroy frog habitats and lead to the degradation of terrestrial habitats based on the study of Goosem (2007).

Improper waste disposal

Wastes such as plastic bottles, wrappers, diapers, and other non-biodegradable materials were observed in some lowland forests and streams. Improper waste disposal can destroy and degrade amphibian habitats (Sunlu 2003).

Dumping waste in forests and streams can disrupt amphibian foraging and breeding areas, making it more difficult for them to find suitable habitats (Figure 16).

Presence of invasive species

Invasive alien species (IAS) significantly threaten biodiversity and negatively affect many taxa. The invasive species *R. marina* and *H. erythraea* were recorded in lowland forests and grasslands during the survey. In the Philippines, these two species are considered invasive, characterized by high reproduction rates, opportunistic feeding habits with broad diets, and high adaptability to harsh environments (David et al. 2017). Moreover, invasive species can disrupt the natural ecosystem dynamics, leading to cascading effects in the food web (Walsh et al. 2016). Native frogs may experience declines in population sizes due to the combined effects of competition, predation, and disease transmission from invasive species (Bucciarelli et al. 2014; Kraus 2015).

Conservation recommendations

Amphibians represent a diverse and unique group of vertebrates, and they contribute to the overall biodiversity of ecosystems, making them significant components of a healthy ecosystem. Given the severe threats amphibians are facing, it is imperative to implement effective conservation management recommendations. The following are conservation measures to avoid further losing amphibians and their habitats. Therefore, by implementing the recommendations below, communities and stakeholders can work together to mitigate the negative impacts of threats towards amphibians and their habitats to ensure the protection and long-term health and sustainability of natural environments.

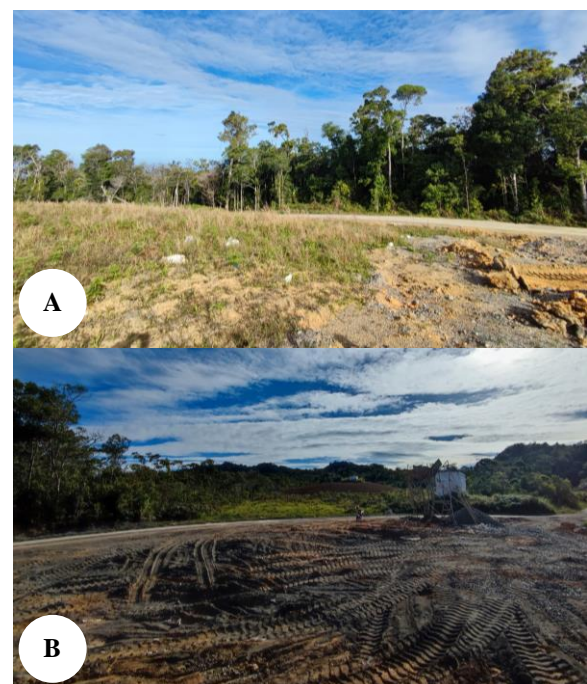


Figure 15. Ongoing road development connecting the two barangays: A. Osorio Dos; B. Bulan-Bulan



Figure 16. Dumped wastes in some areas surveyed. A and B. Forests; C and D. Streams

Declaration of CPMR as a protected area

The CPMR harbors unique biodiversity and provides various ecological services to Panay. Despite its importance, CPMR is not legally protected, and the declaration of the Central Panay Mountain Range as a protected area is a significant step in preserving its ecological, cultural, and economic value for present and future generations while ensuring its sustainable management and conservation.

Road development

Mitigation measures should be implemented to lessen negative impacts such as illegal occupation, establishment of settlements, illegal cutting and collection of wildlife and their by-products, and introduction and proliferation of exotic and invasive species. This entails more assertive policy, implementation of policies, and enforcement. Actively involving and engaging with the existing local communities, especially with the People's Organizations and individuals with tenurial instruments such as Community Based Forest Management Agreement (CBFMA) and Certificate of Stewardship Contract (CSC), is essential in the management and protection of the area.

Waste management

Implementation should focus on preventing pollution, restoring affected areas, and promoting responsible waste management practices to avoid further disturbances. The local government should implement recycling programs and encourage communities near the forests and streams to practice waste reduction and community recycling. Also, accessible and adequately managed waste disposal facilities like recycling centers and composting sites are needed. Regular litter cleanup programs should be organized with local communities and volunteers. Engaging the community in cleanup activities can instill a sense of ownership and responsibility for the environment. There is also a need to enforce strict implementation of existing waste disposal regulations and establish penalty fees for illegal dumping of wastes in forests and streams. Moreover, the local government and barangay councils should initiate restoration programs such as cleaning up contaminated sites and planting native trees in significant areas affected by improper waste disposal.

Habitat rehabilitation

Areas strategically located close to patches of forests known to harbor populations of endemic amphibians and other threatened wildlife species should be priority areas for habitat rehabilitation, as should those areas surrounding the watershed. Rehabilitation should also ensure that only plant species known to occur on the island are replanted and propagated.

Conservation education and awareness

Community-based biodiversity conservation education activities tailored to the specific needs and interests of the local communities should be conducted to raise awareness and appreciation of the unique wildlife and habitat importance of CPMR for effective conservation management.

Eradication of invasive species

Dealing with invasive alien species (IAS) is an ongoing and complex challenge, and the effectiveness of management efforts can vary depending on the specific species and the extent of their impact. Regular monitoring should be conducted to detect the status of invasive species and prevent further damage. The negative impacts of IAS should be highlighted during public awareness activities, and manual removal should be introduced. Comprehensive and coordinated strategies and public support are essential to addressing this pressing issue.

Additional research

The Central Panay Mountain Range is a vast area, and several sites still have yet to be surveyed, and some areas need information updates. The CPMR forest territory still significantly contains sections of lowland forest and upper montane forests with limited information where it holds significant information on the presence of restricted range and threatened amphibians. Conducting biological research in other areas for extended periods is deemed significant in providing a baseline or update on their biological and ecological status. The information gathered will then provide more significant data for extrapolating the population and status of threatened and restricted-range species and, most importantly, for species and habitat management in the area.

In conclusion, amphibians are considered important biological indicators of a healthy environment. However, because of the imminent threat of environmental change and the decreasing forest cover in CPMR, amphibians may continuously face population decline. Through comprehensive surveys across diverse habitats, the study revealed moderately diverse amphibian species, including endemic and threatened species, highlighting the value and importance of CPMR. The documentation of new distribution records and unidentified species further emphasizes the need for continued research to enhance the understanding of amphibian ecology and diversity in CPMR. Despite the area's ecological richness, the study revealed local threats such as ongoing road development, improper waste disposal, invasive alien species, *Rhinella marina* and *H. erythraea*, and overharvesting. Various conservation measures have been proposed to address these challenges effectively, encompassing mitigation activities during road development, waste management, wildlife protection, habitat rehabilitation, conservation education, awareness initiatives, eradication of invasive species, additional research activities, and the declaration of CPMR as a protected area. Implementing these targeted conservation measures, coupled with collaborative partnerships among relevant stakeholders, is the key to ensuring the long-term conservation of amphibians, their habitats, and the overall biodiversity and ecological integrity of CPMR.

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