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Herpetofauna of forest fragments within the Agata Mining Ventures Incorporated (AMVI), Agusan del Norte, Caraga Region, Philippines

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ABSTRACT

The Philippines holds an extraordinary record of amphibian and reptile diversity and endemism; however, factors like habitat loss and fragmentation that may result from activities related to resource extraction, such as mining, pose a significant threat to their conservation. This study examined the herpetofauna composition in select forest fragments within one of the important mining sites in Caraga, the Agata Mining Ventures Incorporated, between 2018 and 2021. Standardized time searches along the established two 2km transects in two sampling stations (Lawigan and Tinigabasan) were conducted to record reptiles and amphibians accounting for 880 man-hours. In both surveys, 513 individuals representing 12 species of amphibians and 17 species of reptiles were recorded in the area. Of these species, 62% (n = 18 spp.) are Philippine endemic, 35% (n = 10 spp.) native, and 3% (n = 1 spp.) are invasive alien species. Overall, the Shannon-Weiner diversity index is high (H'=2.52) and varied significantly across survey periods (Mann-Whitney U test = 248.5, p=0.007). The species-area relationship analysis showed a strong positive correlation for total herpetofauna ($R^2 = 0.98$), amphibians ($R^2 = 0.87$), and reptiles ($R^2 = 0.99$), and a significant correlation existed between reptiles and forest area ($p = 0.05$). The result suggests a strong reliance of herpetofauna richness in forested areas. Combined forest clearing and the effects of mining activities in the area might threaten these environment-sensitive taxa. Preserving these forest fragments within AMVI and allocating buffer zones is highly recommended. Periodic scientific field-based surveys and re-surveys, encompassing not only amphibians and reptiles but also various other species, are recommended to monitor species distributions, population trends, and impacts of ongoing activities. These efforts aim to update data-driven sources supporting the mining area's rehabilitation program, contributing to societal and environmental benefits.

Keywords: *amphibians, monitoring, mining environment, reptiles, species-area relationship*

1 Introduction

The Philippines is recognized as an important center of herpetofauna diversity in Southeast Asia (Diesmos et al. 2002). Currently, the country supports 118 amphibian species (Sy 2022) and 361 reptile species (Uetz et al. 2018). Mindanao, in particular, is known to harbor high biodiversity, specifically herpetofaunal diversity (Brown et al. 2013, Diesmos et al. 2015, Abdullah et al. 2023).

Aside from being recognized as a megadiverse country, the Philippines also ranks 5th as the most mineral-rich country in the world for mining gold, copper, nickel, and other metallic minerals (MGB-DENR 2013). It has been recognized that surface mining can potentially displace topsoil and vegetation (Wickham et al. 2013), and pollution in surface waters brought about by the processing of mined materials is one of the major problems in mining areas (Fletcher et al. 2006). Unfortunately, mining concessions overlap with the Eastern Mindanao Biodiversity Corridor, which is recognized as one of the designated Key Biodiversity Areas (KBA) (Critical Ecosystem Partnership Fund 2001). This overlap poses a threat and pressure to biodiversity, particularly the environment-sensitive herpetofauna.

Studies on herpetofauna in the Philippines are progressively increasing. In Mindanao, several explorations are conducted in mountains, forested habitats, caves, and watersheds (Supsup et al. 2017, Nuñeza and Galorio 2015, Sanguila et al. 2016, Sanguila et al. 2020) but not sufficiently in mining areas. Mining activities are believed to pose a significant threat to herpetofauna, yet it has received limited research attention (Mayani-Paras et al. 2019). Research on herpetofauna in mining areas has been constrained, with surveys only conducted in Tumbagon, Cagayan de Oro City (Ascaño et al. 2015a b), Agusan del Sur, and Surigao del Norte (Galolo et al. 2021). Mindanao, the center for herpetofauna endemism (Sanguila et al 2016), needs more studies on herpetofauna, particularly in mining areas. Amphibians and reptiles are good biological indicators of environmental health because their presence provides baselines for assessing habitat conditions and restoration success (Mifsud 2013). Amphibians are sensitive to environmental changes such as climatic and land-use alterations (Hof et al. 2011), acidification (Gibbons et al. 2000), and metal contaminants (Christy and Dickman 2002). Reptiles are also good bio-indicators in mine sites due to their ease of sampling, defined activity areas and periods, long life spans, complex and diverse community structures, and different size ranges (Thompson and Thompson 2005).

Amphibians had a higher species threat index than birds and mammals, and reptiles remained the least studied group among terrestrial vertebrates (Abdullah et al. 2023). Hence, a study on amphibians and reptiles within barangay Lawigan and Tinigbasan of Agata Mining Ventures Inc. (AMVI) was conducted in 2018 and 2021. Repeated surveys are essential to determine species occurrences, thereby assessing their diversity and conservation status (Supsup et al. 2017). The two barangays were explored to document the herpetofauna species present, highlighting the endemic, threatened, and socio-economically important species. This study will give preliminary information on priority taxa in the forest fragments within AMVI for species conservation and the creation of mitigation programs to reduce the impact of mining activities.

2 Materials and Methods

Study Site

Agata Mining Ventures Incorporated is located in Agusan del Norte, Mindanao, Philippines, with geographical coordinates between 09°14'43 "N and 125°32'36 "E. The mine area is about 3.5 kilometers from its own seaport. Agusan del Norte falls under a Type II climate, characterized by the absence of a dry season and a distinct peak in rainfall from December to February. There is no month without rainfall, and the minimum monthly rainfall occurs from March to May (DA-BSWM 2017). Tubay receives an average annual precipitation of about 81.33mm (3.2in), a humidity of 82.61%, and an average temperature of 23.48ºC (74.26ºF) to 32.61ºC (90.7ºF) (Weather and Climate 2023)

Herpetological surveys were conducted between June 5-8, 2018, and November 3-12, 2021, in two sampling stations: Barangay Lawigan and Barangay Tinigbasan, Tubay, Agusan del Norte, within the Mineral Production Sharing Agreement (MPSA) of Agata Mining Ventures Incorporated (Figure 1). Within each station, two 2-km transect lines were laid. In each transect line, six 10 x 100-meter strip transects were established randomly (Supsup et al. 2016).

The habitat types in the area are dominated by early secondary growth (ESG) forest, brushland (BRL), and cultivated areas (CVT) with patches of advanced secondary growth (ASG) forest, agroforest (AF), and grassland with elevation ranging from 24masl to 455masl (Figure 2). Coconut (*Cocos nucifera*) and Falcata (*Falcataria falcata*) plantations are common in the area. Several tree species, such as Alagasi (*Leucosyke*

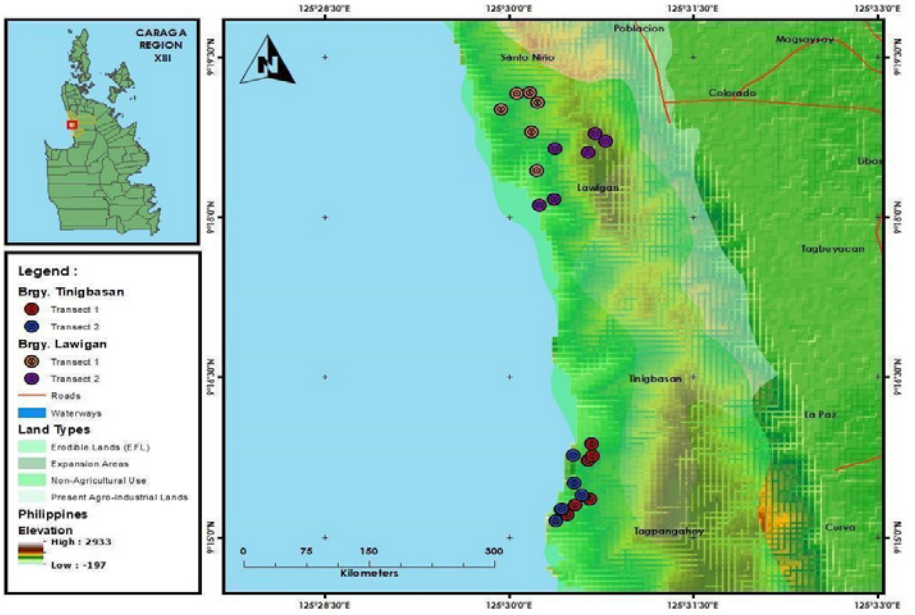

Figure 1. Amphibians and reptiles sampling sites within Agata Mining Ventures Incorporated (AMVI), Tubay, Agusan del Norte, Philippines.

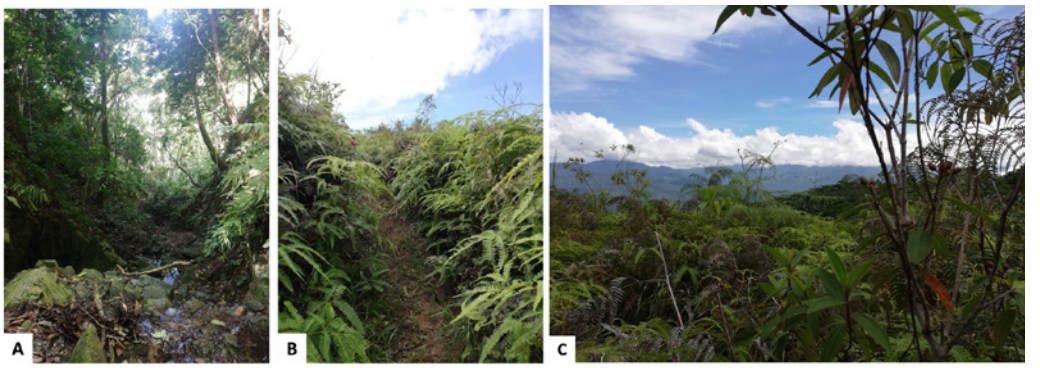

Figure 2. Vegetation within Agata Mining Ventures Inc.: A. Early secondary growth forest within the lowland areas, B. Thick agsam (*Lygodium circinnatum*) vegetation along the forest ridge, and C. Panoramic view of the forest fragments within AMVI.

capitellata), Narra (*Pterocarpus indicus*), Molave (*Vitex parviflora*), and Antipulo (*Artocarpus blancoi*) were also recorded along streams of sampling stations.

Herpetofaunal Surveys and Identification of Samples

Extensive diurnal (1000 to 1500h) and nocturnal (1900 to 2200h) opportunistic surveys of amphibian and reptile populations were conducted, accounting for 880 man-hours in searching and traversing all the sampling stations. Morphometric measurements of each sample were measured on-site, such as snout-vent length (SVL), head length (HL), Head width (HW), Forelimb length (FL), and Leg length (LL) using a vernier caliper or ruler, and the weight through a digital weighing scale to aid in the identification. After measuring and processing, species were photographed, marked, and released back into the environment. The catch-and-release method was employed using water-based paint to avoid

duplication of counts. No voucher specimens were collected.

Species were identified using published photographic guides and identification keys, using the Philippine Checklists of Alcala et al. (2015), Diesmos et al. (2015), and Sanguila et al. (2016). The conservation status of the recorded species was determined using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (version 2022-2) and the DENR Department Administrative Order (DAO) No. 2019-09. DAO conservation assessment is a National Red List that evaluates the status and extinction risks of local species limited to Philippine populations instead of IUCN considering global distribution. Both were used to determine the conservation status of recorded species.

Data Analysis

Cluster analysis using Jaccard's abundance-based similarity matrix was conducted to analyze species' resemblances between survey periods. Biodiversity indices were also computed to aid in the comparison of species composition across survey periods; these include species richness (S), abundance (N), Shannon-Weiner diversity (H'), and evenness (J). Species diversity was characterized using the following criteria: If H' <1, the species diversity is considered low. The species diversity is moderate if H' is between 1 and 1.5. If H' is between 1.6 and 3, the species diversity is high, while if H'>3, the species diversity is extremely high (Odum 1971 as cited by Jalil et al. 2020). Mann Whitney U-Test was also used to determine the significant differences between sampling years using Paleontological Statistics (PAST) software ver 4.11. The species–area curve depicts the relationship between species richness and the transects surveyed. To enhance the curve's interpretability, logarithmic transformations ($\log_{10}$ values) were applied to both species and land area values, and the resulting data were subjected to linear regression. R^2 and p-values were computed for each regression analysis, serving as metrics to quantify the deviation from the regression line and providing a measure of accuracy for the predictive models (Jessee et al. 2022). Linear regression and scatter plots were performed using JASP version 0.18.1 software.

3 Results and Discussion

Species Composition and Endemicity

In total, 513 individuals of herpetofauna belonging to 13 families, 25 genera, and 29 species were recorded within the forest fragments of Agata Mining Ventures Incorporated (Table 1 and Figure 5-6). Anurans accounted for 80.9% (N = 415 individuals, n = 12 spp) of the total population captured, and 19.1% (N = 98 individuals, n = 17 spp) were reptiles. The record represents 18.13% of the Mindanao records (Agduma et al., 2023) and 6.05% of the entire Philippine herpetofauna (Sy 2022, Uetz et al. 2018). Among anurans, the family Dicroglossidae, composed of semi-aquatic frogs, was the most species-rich (n = 4 spp., 34%). In contrast, the family Bufonidae, Megophryidae Microhylidae yielded the lowest number of species recorded (n = 1 spp., 8%). *Limnonectes magnus* had the most individuals (35.18%), followed by *Pulchrana grandocula* with 16.63%. (Figure 3A). For the reptiles, the family Scincidae had the highest number of species (n = 5 spp., 29%), while families Lamprophiidae and Geoemydidae, each represented by a single species (n = 1 spp., 6%). *Gekko gecko* from the family Gekkonidae gained the most individuals across sampling stations (7.49%, Figure 3B).

Regarding endemicity, 62% of the species recorded were Philippine endemic, 35% were non-endemic, and 3% were Invasive Alien Species (Figure 4A). Most of the herpetofauna recorded in the fragmented forests were categorized as least concern species (93%) as listed in the IUCN Red List of Threatened Species (Figure 4B). It is also notable for recording one endangered species, *Coura philippinensis* (3%) in the area. Five species (17.24%) were listed as Other Threatened Species, namely *L. magnus, Megophrys stejnegeri, Hydrosaurus pustulatus, Gekko gecko* and *C. philippinensis* based on Philippine Red List Status (DAO 2019-09). Most amphibians and reptiles have decreasing population trends (n = 11 spp., 38%). These species are not critically endangered, endangered, or vulnerable but are known to face anthropogenic threats and might be moved to a threatened category in the future. The socio-economically important anuran, *L. magnus*, was abundantly recorded in both surveys. This species is primarily known to be harvested and exploited for food by the local community. Gonzalez et

Table 1. The list of herpetofauna recorded in the two sampling stations in Tubay, Agusan del Norte during the field samplings with their corresponding Endemicity, IUCN's conservation status (CS), Population Trend, DAO 2019-09 status, and abundance (relative abundance).

Taxa	Common Name	Endemicity	CS, Pop'n trend	PRLS	Abundance (Relative Abundance)	
					2018	2021
Amphibians						
Bufonidae						
Rhinella marina (Linnaeus, 1758)	Cane Toad	IAS	LC, ↑	-	22 (10.68)	10 (3.26)
Ceratobatrachidae						
Platymantis guentheri (Boulenger, 1882)	Gunther's wrinkled ground frog	ME	LC, ↓	OWS	-	3 (0.98)
Platymantis dorsalis (Duméril, 1853)	Common forest frog	PE	LC, ↓	OWS	-	1 (0.33)
Dicroglossidae						
Fejervarya vittigera (Wiegmann, 1835)	Luzon Wart Frog	PE	LC, ↓	OWS	-	1 (0.33)
Limnonectes magnus (Stejneger, 1909)	Mindanao Fanged Frog	PE	NT, ↓	OTS	90 (43.69)	56 (18.24)
Limnonectes leytensis (Boettger, 1893)	Leyte Wart Frog	PE	LC, ↓	OWS	3 (1.46)	16 (5.21)
Occidozyga laevis (Günther, 1858)	Philippine Oriental Frog	NE	LC, ↓	OWS	3 (1.46)	22 (7.17)
Microhylidae						
Kalophrynus sinensis Tschudi, 1838	Black-spotted sticky frog	NE	LC, ↓	OWS	-	33 (10.75)
Megophyridae						
Megophrys stejnegeri (Taylor, 1920)	Mindanao Horned Frog	PE	LC, ?	OTS	6 (2.91)	18 (5.86)
Rhacophoridae						
Polypedates leucomystax (Gravenhorst, 1829)	Four-lined tree Frog	NE	LC, -	OWS	25 (12.14)	35 (11.40)
Kurixalus appendiculatus (Günther, 1858)	Philippine Flying Frog	PE	LC, ↓	OWS	-	2 (0.65)
Ranidae						
Pulchrana grandocula (Taylor, 1920)	Big-eyed Frog	PE	LC, -	OWS	35 (16.99)	34 (11.07)
Reptiles						
Lizards						
Agamidae						
Draco bimaculatus Günther, 1864	Two-spotted Flying Lizard	NE	LC, -	OWS	2 (0.97)	6 (1.85)
Draco cyanopterus Peters, 1867	Flying Dragon	ME	LC, -	OWS	2 (0.97)	-
Hydrosaurus pustulatus (Eschscholtz, 1829)	Phil. Sailfin lizard	PE	LC, ↓	OTS	7 (3.40)	9 (2.93)
Gekkonidae						
Cyrtodactylus agusanensis (Taylor, 1915)	Agusan Bent-toed Gecko	ME	LC, ?	OWS	1 (0.49)	3 (0.98)
Gehyra mutilata (Wiegmann, 1834)	Stump-toed Gecko	NE	LC, -	OWS	-	1 (0.33)
Gekko gecko (Linnaeus, 1758)	Tokay gecko	NE	LC, ?	OTS	-	23 (7.49)
Scincidae						
Brachymeles orientalis Brown & Rabor, 1967	Southern Burrowing Skink	PE	LC, ?	OWS	-	5 (1.63)
Eutropis multicarinata (Gray, 1845)	Two-striped Mabouya	ME	LC, -	OWS	-	3 (0.97)
Eutropis multifasciata (Kuhl, 1820)	Common Mabuya	NE	LC, -	OWS	-	1 (0.33)
Pinoyscincus coxi (Taylor, 1915)	Cox's Sphenomorphus	PE	LC, ?	OWS	1 (0.49)	2 (0.65)
Tropidophorus misaminius Stejneger, 1908	Misamis Waterside Skink	ME	LC, -	OWS	4 (1.94)	6 (1.95)

Legend: Conservation Status (CS) based on IUCN 2022 = EN-Endangered, NT- Near Threatened, LC-Least Concern, DD-Data Deficient; Population Trend: (↓) – decreasing, (↑) – increasing; (-) – stable, and (?) – unknown. Endemicity = IAS -Invasive Alien Species, PE- Philippine Endemic, NE-Non-Endemic, ME- Mindanao Endemic. Philippine Red List Status (PRLS) based on DAO 2019-09: VU – Vulnerable; OTS – Other Threatened Species; OWS – Other Wildlife Species

Table 1. Continuation. The list of herpetofauna recorded in the two sampling stations in Tubay, Agusan del Norte during the field samplings with their corresponding Endemicity, IUCN's conservation status (CS), Population Trend, DAO 2019-09 status, and abundance (relative abundance).

Taxa	Common Name	Endemicity	CS, Pop'n trend	PRLS	Abundance (Relative Abundance)	
					2018	2021
Snakes						
Colubridae						
Ahaetulla prasina preoccularis (Boie, 1827)	Gunther's whip snake	NE	LC, -	OWS	1 (0.49)	5 (1.63)
Chrysopelea paradisi H. Boie in F. Boie, 1827	Garden Flying Snake	NE	LC, -	OWS	1 (0.49)	-
Dendrelaphis philippinensis (Günther, 1879)	Mindanao Stripe-tailed Bronzeback	PE	LC, -	OWS	1 (0.49)	-
Lycodon capucinus H. Boie in F. Boie, 1827	Common Wolf Snake	NE	LC, -	OWS	1 (0.49)	2 (0.65)
Lamprophiidae						
Oxyrhabdium modestum (Duméril, 1853)	Phil. Shrub Snake	ME	LC, ↓	OWS	1 (0.49)	8 (2.60)
Turtle						
Geoemydidae						
Cuora philippinensis (Riche in Daudin, 1801)	Southeast Asian Box Turtle	PE	EN, ↓	OTS	-	2 (0.65)

Legend: Conservation Status (CS) based on IUCN 2022 = EN-Endangered, NT- Near Threatened, LC-Least Concern, DD-Data Deficient; Population Trend: (↓) – decreasing, (↑) – increasing; (-) – stable, and (?) – unknown. Endemicity = IAS -Invasive Alien Species, PE- Philippine Endemic, NE-Non-Endemic, ME- Mindanao Endemic. Philippine Red List Status (PRLS) based on DAO 2019-09: VU – Vulnerable; OTS – Other Threatened Species; OWS – Other Wildlife Species.

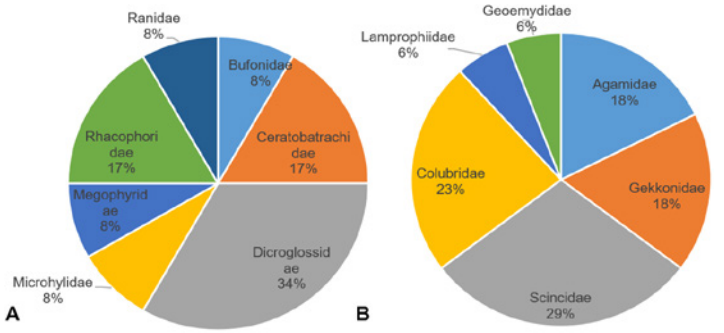

Figure 3. Family composition of (A) amphibians and (B) reptiles collected in the forest fragments of AMVI, Tubay, Agusan del Norte.

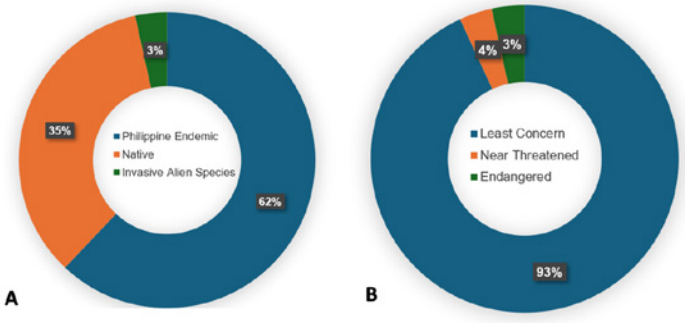

Figure 4. Status of the herpetofauna species (A) Endemicity and (B) IUCN Red List collected in the area.

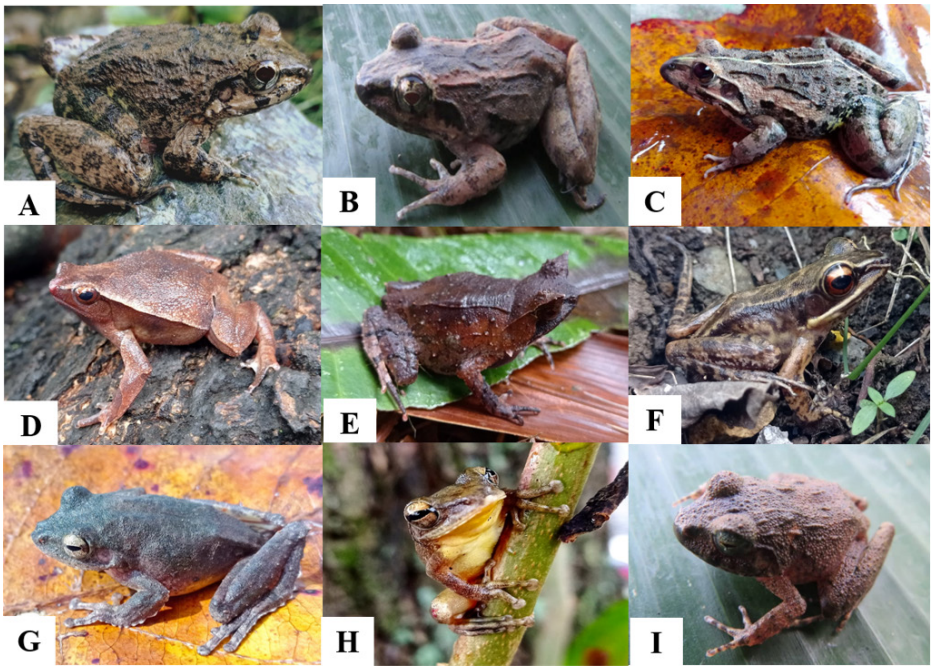

Figure 5. Some Amphibians of AMVI, Tubay, Agusan del Norte: (A) *Limnonectes magnus*, (B) *Limnonectes leytensis*, (C) *Fejervarya vittigera*, (D) *Kalophrynus sinensis*, (E) *Megophrys stejnegeri*, (F) *Pulchrana grandocula*, (G) *Kurixalus appendiculatus*, (H) *Platymantis guentheri*, and (I) *Platymantis dorsalis*.

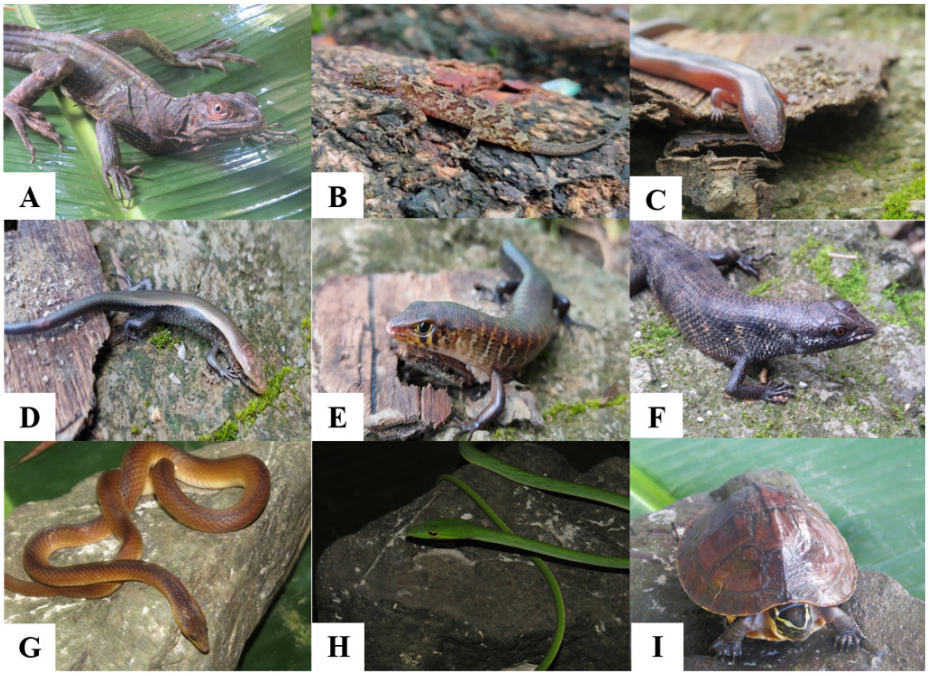

Figure 6. Some Reptiles of AMVI, Tubay, Agusan del Norte: (A) *Hydrosaurus pustulatus*, (B) *Cyrtodactylus agusanensis*, (C) *Brachymeles orientalis*, (D) *Eutropis multicarinata*, (E) *Tropidophorus misaminius*, (G) *Oxyrhabdium modestum*, (H) *Ahaetulla prasina preoccularis*, and (I) *Cuora philippinensis.*

al. (2018) identified three threat criteria for herpetofauna in the Philippines: illegal wildlife trade, habitat loss, and hunting or overharvesting. Both habitat loss and hunting for subsistence or local commerce were observed in the survey area. This observation coincides with the study of Abdullah et al. (2023) that showed habitat loss driven by deforestation and the collection of wildlife for consumption, threatening a high proportion of herpetofauna in Mindanao.

Furthermore, an alarming presence of the invasive alien species, *Rhinella marina* was also recorded in the area. This species is known to have a high degree of spatial and dietary overlap with native frogs, leading to potentially intense competition (Diesmos 2008). The key threats and the documented presence of invasive species could potentially endanger native amphibian populations in the area.

Compared to studies in mining areas within Mindanao, a study conducted by Galolo et al. (2021) recorded 35 amphibians in select mining areas (1. Masabong, Rosario, Agusan del Sur; 2. Philsaga Mining Corporation, Agusan del Sur; 3. San Andres, Bunawan, Agusan del Sur; and 4. Adnama Mining Resources Incorporated (AMRI), Claver, Surigao del Norte) within the Caraga Region. Noteworthy is that all of the amphibians recorded in AMVI were also recorded in other regional mining areas. Another study conducted within and outside the Hydraulicking Mining area in Tumpagon, Cagayan de Oro City, recorded 13 species of anurans and 17 reptiles (Ascaño et al. 2015a,b). This record aligned with the current study that recorded the same number of amphibians and reptiles in a nickel mining environment. The presence of the recorded species in other mining sites in Mindanao indicates the tolerance of these species to disturbances brought about by mining activities. However, it might lead to local declines when not given enough attention for conservation.

Species Diversity Between Survey Periods

Comparing the surveys, the 2018 herpetofauna inventory recorded 18 species of herpetofauna (7 amphibians and 11 reptile species), while the 2021 survey recorded 26 species (12 amphibians and 14 reptile species). Eleven species namely; *Platymantis guentheri, Platymantis dorsalis, Fejervarya vittigera, Kalophrynus sinensis, Kurixalus appendiculatus, Gehyra mutilata, Gekko gecko, Brachymeles orientalis, Eutropis multicarinata, Eutropis multifasciata,* and *C. philippinensis* were new records for AMVI. Species abundance and diversity were significantly highest during the 2021 herpetofauna survey, N=307, and H'=2.73, respectively (Mann-Whitney U test = 248.5, p=0.007). Overall, species diversity within the remaining forest fragments of AMVI is high, H'=2.52. Jaccard's Abundance-based similarity index between the survey periods was 0.525 (Table 2).

Factors contributing to the observed variations in detected species between the sampling years of 2018 and 2021 could include influences from diverse environmental conditions. In 2018, the sampling period coincided with the rainy season, potentially affecting the presence and distribution of species due to weather-related factors. Additionally, mining operations could alter species' behavior and interspecies interactions, contributing to the observed differences in species composition. Conversely, in 2021, reduced human visitation to the sites, a consequence of pandemic-

Table 2. Diversity Indices and comparison between survey periods in forest fragments within Agata Mining Ventures Incorporated, Tubay, Agusan del Norte, Philippines.

Biodiversity Index	Survey Period		Overall
	2018	2021	
Species Richness (S)	18	26	29
Species Abundance (N)	206	307	513
Shannon-Weiner (H')	1.89	2.73	2.52
Evenness (J)	0.37	0.59	0.43
p-value	0.007*		
Jaccard Abundance-based similarity index	0.525		

Tested at $\propto$=0.05 using Mann Whitney U-Test

related restrictions, may contribute to an increased number of observed species due to reduced mining activity and less destruction of habitats.

Despite these variations, notable consistencies emerge in species composition. The surveyed areas within Agata's Mineral Production Sharing Agreement (MPSA) sampling stations (Brgy. Tinigbasan and Lawigan) both exhibited early secondary growth (ESG) forest, brushland (BRL), and cultivated areas (CVT) with patches of advanced secondary growth (ASG) forest, agroforest (AF), and grassland. This similarity in vegetation structure suggests that habitat types within the MPSA provide relatively diverse species of amphibians and reptiles.

Furthermore, habitat variability, food sources, and substantial microhabitats of the sampling stations influence species composition and diversity. For instance, barangay Lawigan is largely covered by ground vegetation and the creeks' damp areas, with huge trees forming scattered tree patches. The primary ground vegetation, however, was made up of new growth of several species of ferns and various plant species, which serve as suitable shelter for ground-dwelling amphibians and reptiles. Both sampling stations had secondary-growth forests (Along et al. 2020, Sarmiento 2020) and agroforest and grassland vegetation.

Species-Area Relationship

The relationship of species richness to area was positively correlated and accounted for a large portion of the variation for total herpetofauna (R^2 = 0.98), amphibians (R^2 = 0.87), and reptiles (R^2 = 0.99) (Figure 7) which means that for the fragmented forest studied, herpetofauna adheres more closely to the species-area relationship, proving the dependence of amphibians and reptiles on their habitats. This data coincides with the study of Jessee et al. (2022), wherein total herpetofauna and amphibians had a strong, positive correlation to land area.

Amphibian abundance and richness are known to be influenced by the size of the forest area. Due to their limited mobility, strong tendency to remain in their established habitats, and susceptibility to desiccation, amphibians could be especially at risk when faced with habitat fragmentation (Wind 1999). A significant correlation existed between reptiles and forest area (p = 0.05), also recorded in the study. Reptiles are highly sensitive to changes in landscape configuration and condition. Habitat modification is the primary driver of declines in the reptile population (Doherty et al. 2020). Snakes manifested to have the sharpest declines in the fragmented forests (Diesmos 2008). A study conducted by Mayani-Paras et al. (2019) showed that the combined negative impacts of mining and habitat loss resulted in decreased distribution and a potential increase in species extinction to endemic reptiles.

Furthermore, according to Loehle et al. (2005), reptile richness was most pronounced at sampling locations characterized by the lowest basal area (BA) stands, while amphibians exhibited the highest richness at points with the highest BA within the forest landscape. These differences in habitat requirements suggest protection for the area's remaining early and advanced secondary-growth forests. Although fragmentation led to a cascading decline in herpetofauna, with 15–94% of the overall species diversity disappearing in forest fragments, these fragments can play a crucial role as essential refuge sites for rare endemics and those facing threats (Diesmos 2008).

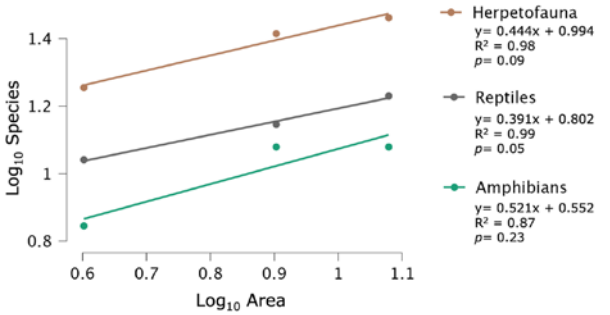

Figure 7. Species-Area relationship of herpetofaunal richness. Log_{10} of species richness and area with regression equation, R^2 and p-values.

The recorded herpetofauna in the sampling stations indicate that the remaining surviving blocks of forests in the study area still provide foraging sites and habitats for reproduction, especially for endemic species. However, if conservation efforts are not prioritized, habitat fragmentation and forest degradation can lead to species decline, losses, and extinction (Solania et al. 2020). Most of the endemic species are forest-dependent organisms and very vulnerable to changes in the ecosystems because they depend so much on the services provided by the forest, such as protection from predators, food, refuge, and shelter (Thompson et al. 2009).

Amphibians and reptiles are known as biological and environmental indicators. These organisms are susceptible to the impacts of mining and mining activities. However, the remaining forest fragments within AMVI still harbor different species of amphibians and reptiles, including threatened species, which suggests actions for conservation. Maintaining the remaining reserves of early and mature stands within the mining area and allocating buffer zones from the forest habitat is recommended. Identifying key habitat attributes for protection, such as aquatic habitats (rivers, streams, and ponds) and habitats that provide cover and moisture, is essential to conservation. Also, reducing reliance on non-native tree crop species for plantation, afforestation, or reforestation projects within the study area might be included in the biodiversity management plan of the mining company.

4 Conclusion and Recommendations

Even with fragmented forests, the area still harbors endemic, threatened, and socio-economically important herpetofauna. These environment-sensitive species indicate the good habitat quality of the remaining forest fragments. Regular monitoring, herpetofauna and habitat associations, and population dynamics studies are important to inform effective herpetofauna conservation in the area. The data from the study would be a baseline for policy reforms to balance socio-economic development and biodiversity conservation.

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution Statement

Apple Rosales and John Patrick B. Suhian contributed to the conceptualization, collection, analysis, and interpretation of data. Eve F. Gamalinda was involved in conceptualization, collection, analysis, interpretation, writing, and manuscript revision for publication. As a member of the JESEG Editorial Board, Gamalinda did not participate in the review process. Sherryl L. Paz was responsible for conceptualization and acquiring primary and secondary data. Chennie Solania-Naling played a role in conceptualization, collection, analysis, interpretation of data, writing, and manuscript revision. All authors approved the final manuscript version.

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