*Article*

# Amphibian diversity, endemism and habitat associations within and outside the selected mining sites in Caraga Region, Philippines

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**Abstract**

Being archipelagic, the Philippines has been recognized as one of the centers of high amphibian diversity and endemism. However, the overlap of mining areas with the habitats of these critical environmental indicators has continuously challenged their existence. Thus, we conducted a study assessing the diversity, endemism, habitat associations, and survival envelopes of amphibian species within and outside of the selected mining sites in Caraga region, Philippines. We have documented thirty-four amphibian species, 15 of which are endemic to the country with four solely distributed species in Mindanao Faunal Region. Eleven species were found vulnerable and one near-threatened based on the IUCN classification. Endemism and species diversity were observed to be higher outside than inside of the mining area. It is argued that these results could be attributed to the loss of habitat and forest fragmentation within the mined area. The observed anuran species prefer forest habitat than in an open/disturbed area; however, some of these forest-associates extend their survival envelope at the forest and non-forest area interface. Survival envelopes or niche widths of forest and globally threatened species are narrow, explaining why their populations decline worldwide. The presence of endemic and globally threatened species in the area is inkling for some conservation efforts to be in place, especially for populations with low abundance in the area, such as *P. poecilus, L. parvus, N. spinosus* and *P. acutirostris.*

**Keywords** aerosols; AOT; cloud; rainfall; northern Thailand.

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## 1 Introduction

The diversity, distribution, and abundance of amphibians are argued to be a consequence of processes that involves both biotic and abiotic factors especially on the impacts of heterogeneity of environments (Hamer and Parris, 2011; Shulse et al., 2010, Silva et al., 2011a,b, 2012; Vasconcelos et al., 2009; Babbit, 2005; Burne and

Griffin, 2005; Afonso and Eterovick, 2007; Keller et al., 2009; Silva and Rossa-Feres, 2011). Some of these are landscape-scale factors are distance to forest fragments (Silva et al., 2011a,b) and the distance between bodies of water (Burne and Griffin 2005). Information on amphibian diversity and distribution has been used to assess the impact of anthropogenic disturbance (Hecnar and M'Closkey, 1996; Kiew et al., 1996; David and Pearman, 1997) because their biphasic lifestyle and membranous and permeable skin can provide an early warning of environmental deterioration (Halliday·and Heyer, 1997; Com and Vertucci, 1992; Daniels, 1992; Blaustein and Wake, 1995; Delis et al., 1996; Fisher and Shaffer, 1996). It is for these reasons that this study was conducted. In a study of changes in amphibian species richness and distribution concerning a wide range of habitat changes associated with an active iron ore mine, for example, has shown decreasing richness in undisturbed, partially disturbed, and profoundly disturbed sites (Krishnamurthy and Hussain, 2004). While the Philippines, ranked 5$^{th}$ as the most mineral-rich country in the world for mining gold, copper, nickel, and other metallic minerals (MGB-DENR, 2013), environmentalists and local communities have raised concerns about the impacts of mining. The CARAGA region as the “mining capital” in Mindanao, the Philippines (Caraga Watch, 2009; DENR-MGB-Caraga, 2013, 2014), rich deposits of mineral ores in the region serve as impetus for why mining activities, both large and small, become prevalent. It has open doors for employment and revenues for local government units. However, many of these mining areas are parts of the Eastern Mindanao Biodiversity Corridor, one of the identified Key Biodiversity Areas (KBA) (CEPF, 2001). Undoubtedly, this overlap of mining concessions with KBA poses a controversial issue on biodiversity conservation since these mining areas may also harbor a vast array of organisms, including the amphibians. At present, it is reported that the Philippines has a total of 107 species comprised of 3 species of caecilians and 104 species of frogs (Inger, 1954; Alcala and Brown, 1998, 1999; Brown et al., 2000; Diesmos et al., 2004, 2006; Siler et al., 2007, 2009b, 2010; Brown et al., 2009). Of these, 85% of them inhabit forested areas. Endemism of Philippine amphibians is high, 78.5%, but is likely to increase to about 80% when more new species are described formally, following the lineage species concept (Brown et al., 2008).

The importance of this faunal group has been emphasized in several pieces of literature, emphasizing its integral role in the food chain. Aside from being a food source for predators, they also control the population of insects and pests; thus, they maintain a healthy environment (Bersano et al., 2013). Moreover, amphibians’ health as a taxon is thought to indicate the biosphere's health as a whole (Hero and Kriger, 2008). Since mining directly impacts the existing vegetation, particularly surface mining, which displaces or removes the current plant cover (Lloyd et al., 2002), it is considered undesirable from a conservation point of view. Vegetation clearance of forest reserves due to mining activities is regarded as the most important reason for biodiversity decline (Naeem et al., 1999). Many of the mining areas operating in Caraga have no extensive assessment of amphibian fauna; thus, information regarding how mining activities affect them is of no avail. Therefore, this study was conducted to assess richness, abundance, endemism, conservation status, habitat association, and survival envelope within and outside selected key mining sites in Caraga region. It is argued that the findings of this study can contribute not only to the bulk of information regarding this faunal group but will also serve as an information guide that is crucial in coming up with effective conservation measures and strategies, particularly in the region.

## 2 Materials and Methods

### 2.1 Study area

The study was conducted within and the surrounding environs of selected vital mining areas in the Caraga Region, Philippines (Fig. 1). Generally, the forest areas in mining sites are highly fragmented due to mining, agricultural activities, logging, and urbanization. There were four sampling sites studied in Caraga region: one small-scale gold mining area in Masabong, Bayugan 3, Rosario, Agusan del Sur, one small-scale gold mining area in San Andres, Bunawan, Agusan del Sur, one large-scale gold mine in Philsaga Mining Corporation, Bayugan 3, Rosario, Agusan del Sur and one large-scale nickel mine at Adnama Mining Resources Incorporated (AMRI), Urbiztondo, Claver, Surigao del Norte (Fig. 2). Two sampling stations were surveyed within and outside of these four key mine sites in the Caraga region, Philippines.

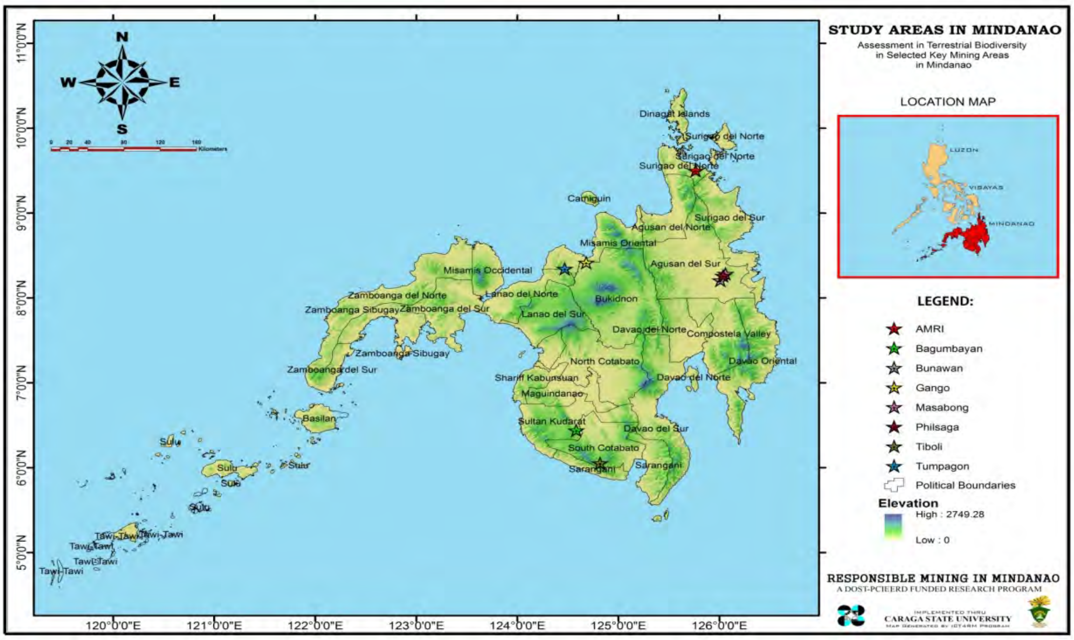


**Fig. 1** The map showing the sampling areas in Caraga region, Mindanao, Philippines.

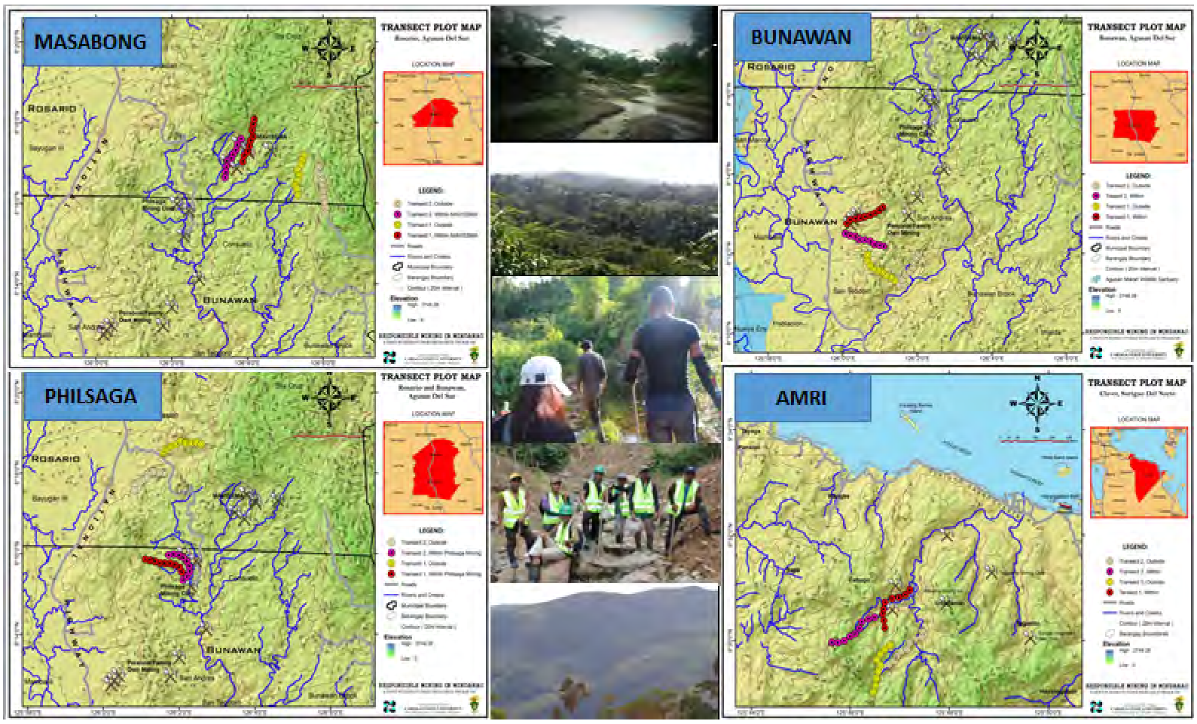


**Fig. 2** Transect plot maps of the four sampling sites in Caraga region, Mindanao, Philippines.

## 2.2 Descriptions of the sampling sites

2.2.1 Sitio Masabong, Bayugan 3, Agusan del Sur

The municipality of Rosario, Agusan del Sur lies between 8023’13.2”N and 12600’10.8”E and has a total land area of 40,272 hectares composed of 20,562.25 hectares of forests, 15,222.8 hectares of agriculture, 4,228.6 hectares of marshland, 197.3 hectares of industrial space and 60.4 hectares of a residential area. The residents’ significant sources of income are farming, fishing, and mining. Natural mineral resources that can be found in the municipality are gold, silver, copper, iron, calcite, barite, crystal quartz, carbon, guano, rock phosphate, clay, and limestone. Rosario has a very minimum rainfall from October to February (DENR-MGB, 2013).

Specifically, Masabong, Bayugan 3, Rosario, Agusan del Sur is where the first legalized People’s Small-scale Mining Area (PSSMA) is located with a total area of 592,393 has. It is located on the southern portion of the Diwata Mountain Range, locally called the Red (Ridge) Mountain. It is situated on one of the distinct physiographic units on northeastern Mindanao, the Eastern Mindanao Ridge, also known as the Eastern Mindanao Gold Province on Central Gold District of the province. This mountain range has a morphologic character reflected by its asymmetric nature: steep, fault-bounded western flank and not so steep eastern slopes. As a product of the tectonic activity, the area is typified by extreme variations of flat to rugged to mountainous terrain. Elevation ranges from 200-280 masl on the lower regions and gentler slopes and about 500 masl on the peaks and mountain tops within the mining area and surrounding parts. Flat terrains or low-lying areas are usually confined along the confluence of some creeks.

The mine site (Fig. 3a-d) has an elevation of 90 – 130 masl and is predominantly composed of old secondary growth forests with patches of shrublands and agricultural/cultivated lands. Anthropogenic disturbances such as logging and clearing were observed near the immediate riparian zone. The two streams (Anahawan and Sinayugan Gamay creeks) are approximately 2-5 meters wide with brownish watercolor. Logs and big rocks were firmly set in some parts of the channel, obstructing streamflow. Detritus commonly present in the stream were leaves and fallen logs.


**Fig. 3** Within the mining site in Barangay Masabong, Bayugan III, Rosario, Agusan del Sur, Philippines. (a) Anahawan creek, (b) Sinayugan Gamay creek, (c) mining tunnel, and (d) houses of mining settlers in the area and Outside the mining site in Sitio Cosip, Barangay Masabong, Bayugan III, Rosario, Agusan del Sur, Philippines, (e) Secondary growth forest, (f) secondary growth forest, (g) deforested area, and (h) falcata plantation.

For the outside the mining region, the site was located in Sitio Cosip, Barangay Masabong, Bayugan 3, Agusan del Sur with an elevation of 339-484 masl and predominantly composed of advanced secondary growth forests and early secondary growth forests (Fig. 3e-h). The sampling area is seven kilometers away from the mining site. Deforestation and forest conversion to agricultural lands or plantations were observed within the region. The color of water in the small streams within the area was evident compared to those in Site 1. Stream banks were stable, made of rocks and soil held firmly by grasses, shrubs, and tree roots. The substrate is mainly composed of sand and big rocks. Mosses in rocks and some fallen logs were present within and along the streams.

2.2.2 San Andres, Bunawan, Agusan del Sur

Bunawan is geographically situated below the typhoon belt but is usually affected by depressions forming in the typhoon regions of Visayas and the province of Surigao del Norte with a type II climate with no dry season, pronounced maximum rainy period occurring in October – January. However, there is no single dry month (PAGASA, 2000). Forestland constitutes 76% of the total land area or 6,827.5 km², while the alienable and disposable constitutes about 24% or 2,137.5 km². However, present land use showed that settlements and the commercial regions already occupy some of the forestlands (Allan and Egirani, 2008).

Bunawan is politically subdivided into ten barangays, including San Andres, which comprises five villages – Sitio Away, Sitio Sinangan, Liboton, Binahanan, and Pinahan. Sitio Away is the most famous and the largest small-scale gold mining area (more or less a hundred has.) but whose mining operations are not legalized due to difficulty in qualifying the evaluation and going through the application process.

The mine site studied was in Sitio Away (Fig. 4a-d), formerly a large-scale copper mine converted to a small-scale gold mine. The area is dominated by cultivation – rubber, falcata, oil palm, coconut, rice, and other crop plantations. Cultivated habitat features dominate the space occupying 48% of the entire sampling site. The presence of crops among various fruiting plants such as the plantation of Durian (*Durio zibenthius*), Makopa (*Syzygium malacense*), Falcata (*Paraserianthis falcataria*), Coconut (*Coccus nucifera)* and different Banana sp. were observed. The cultivated area in Bunawan was characterized by plain land with a rolling surface at some and had an elevation ranging from 21-141 masl. Ferns (pteridophytes) dominate the ground vegetation comprising 70% of ground cover.

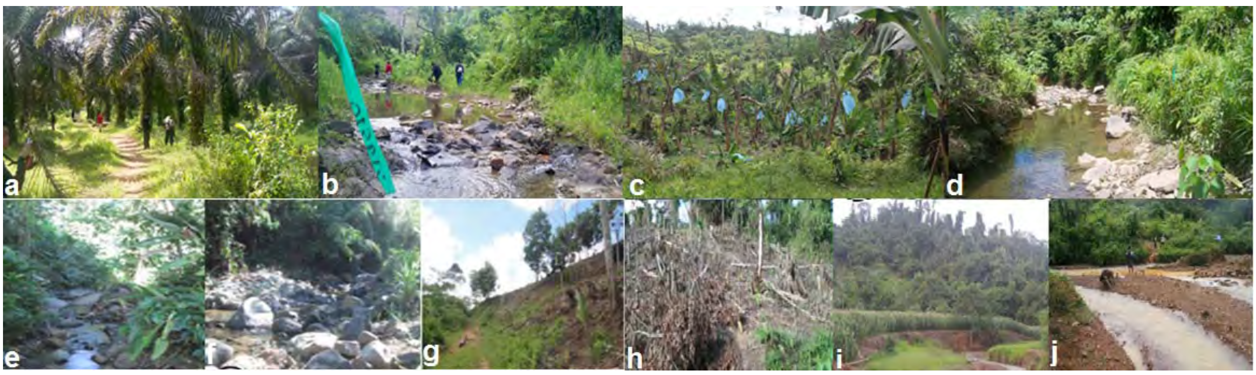


**Fig. 4** Photographs of Sampling sites within the small-scale gold mining area in Barangay San Andres, Bunawan, Agusan del Sur, Mindanao, Philippines (a-d); Outside the mining site in Sitio Tagbayangbang, Barangay Bunawan Brook, Bunawan, Agusan del Sur, Mindanao, Philippines (e-j).

Outside the mining site (Fig. 4e-j), about five kilometers from the mining area, was located in Sitio Tagbayangbang, Brgy. Bunawan Brook, Bunawan lies along (N 08°12.601' and E 126°00.578'), elevating 90-

130 masl. The area is dominated by cultivation with fewer patches of regenerating forests. The anthropogenic activities observed in the area were slash-and-burn farming, logging, and wildlife hunting.

2.2.3 Philsaga Mining Corporation (PMC), Bayugan 3, Rosario, Agusan del Sur

Philsaga Mining Corporation (PMC) is situated in Bayugan 3, Rosario, Agusan del Sur, which is located in the Southern part of Rosario. It is bounded in the North by Brgy. Wasian in the south by Brgy. Consuelo, Bunawan, in the east by Municipality of Bislig, Surigao del Sur, and in the west by La Paz. It consists of 11 villages with a total population of 6,782 of which, 9.2% are Indigenous People (IPs). The total land area of the barangay is estimated to be more or less 11,518 has. The terrain is generally flat, gently sloping, and rolling areas. About 35% consists typically flat, 20% gently to moderately sloping, and 45% hilly to rolling terrain with slopes more than 50%. The said barangay has a type II climate.

The soil type of Bayugan III is Butuan Loam. Other portions, especially on the uplands, are characterized by clay soil and some undifferentiated mountain soil. Soil fertility is identified to be moderately fertile suitable for various crops. The upland areas of the barangay are susceptible to soil erosion. Flash flood occurrence brought about considerable surface runoff and washed out topsoil affecting soil structure and its fertility. This problem is aggravated by the usual mining practice called "padumog" in the hilly areas. A considerable volume of water is poured into a specified surface area to wash out gold particles. Upland and sloping portions get eroded due to the absence of thick vegetative cover, especially forest trees due to illegal logging and kaingin.

The selected sites in the surrounding areas, 5 to 6 kilometers away from the mining site, were at 8° 14' 30" North and 126° 1' 30" East. The elevation ranges from 63 to 258masl, with a slope range of 0° to 54°m. Their primary source of living mainly was vending, mining, and farming. Banana, coconut, falcata, and fruits were among the significant agricultural vegetation observed outside Philsaga. The plant species found in the surrounding forests of Philsaga, Agusan Del Sur were Coconut (*Cocus nucifera*), Banana (*Musa acuminata*), and Falcata (*Albizaria falcataria*) which belongs to the cultivated area. Marang (*Artocarpus odoratissimus*), Basikong Kalauang (*Ficus botrycarpa*), Talisay (*Terminalia catappa*), and Lawaan (*Shorea negrosensis*) were the dominant trees observed in the area (Fig. 5a-d). Several unsafe practices were seen, such as; slash-and-burn farming, deforestation, and illegal logging.

**Fig. 5** Sampling sites within and outside the mining site in Philsaga, Rosario, Agusan del Sur. (a & b) Within the mining area, (c & d) outside the mining area (a-d); Sampling sites in AMRI, Barangay Urbiztondo, Claver, Surigao del Norte. (e & f) Within the mining area, (g & h) outside the mining area.

2.2.4 Adnama Mining Resources Incorporated (AMRI), Urbiztondo, Claver, Surigao del Norte

Surigao del Norte mainland has a varied terrain ranging from flat to rugged to mountainous. The soil in the province is clay and sandy loam type. The land in the mainland area is generally classified as loam, characterized as permeable, moderately drained, and highly suitable for agriculture. The province falls under climate type II characterized by no pronounced dry season but a very pronounced maximum rainfall period from November to January. It has a total rainfall of 3,949.43 mm from the 238 days. Temperature ranges from a low of 21.10°C in October to a high 35.20°C in June. The mainland province has 168,285 (59.69%) forest land, and an estimated 113,630 has (40.31%) alienable and disposable land.

Urbiztondo is one of the fourteen barangays of Claver, Surigao del Norte, with a land area of 1,826.14 $km^2$ divided into plains, hilly mountains, and the coastal regions. Four types of topography characterize the barangay: flat to gently sloping, gently sloping to undulating, undulating to rolling, and rolling to steep. Land use classification in the barangay is mostly forest (53.12%), with a small portion being built-up (less than 1%). Mineral land constitutes a sizeable 33.73% of the total area of the barangay. The agricultural area comprised 12.70% of the barangay land area. As of 2007, the total population of the barangay is 1,544, with an average household size of 5.

AMRI involves extraction through "open cut"/hillslope cutting/cut and fills method and direct shipment of nickel laterite from the MPSA-permitted area in Brgy. Urbiztondo, Claver, Surigao del Norte, with an area of 1,086.50 has. It is located in a ridge juts out into the coastal area fronting the Hinatuan Passage or Candos Bay to some at 9° 30'00" - 9° 33'30" N and 125° 46'00" - 125° 48'30" E.

Areas blocked for mining designated as Block 1,2 and 3 are predominantly grassland vegetation with the sporadic distribution of medium-sized trees dominated by paguspus (*Leptospermum flavescens*), a signature species in ultramafic areas magkono (*Xanthostemon verdugonianus*). Pioneer ferns, lukdo (*Pteridium aquilinum*), and agsam (*Dicranopteris linearis*) appeared to dominate the entire landscape, interspersed with cogon and talahib in some areas. Outside the mining area, about 3 to 4 kilometers from the mining site (Fig. 5e-h)), remnant forest vegetation was observed along cliffs surrounded by diverse agricultural areas planted with coconut trees, bananas, and other cash crops.

**2.3 Collection of samples and environmental data**

A total of 20 transect lines were established per sampling site. Ten 100-meter transect lines were laid within the mine site and another ten 100-meter transect lines outside the mining area. These transect lines were at least 50 meters apart and divided into ten sampling points. These are where visual survey and habitat assessment were conducted. The Geographical Positioning System (GPS) was used to determine the locations of all sampling points accurately.

Several habitat variables were noted during the sample collection, including altitude (ELEV), temperature (TEMP), relative humidity (HUM), percentage grass (MD1), percentage shrub (MD2), percentage tree (MD3), number of standing dead trees (OD2), number of down logs (OD3). The elevation of each sampling point was determined using an altimeter. The geographic coordinates of each sampling point were recorded using an etrex Vista HCx Garmin GPS. The degree of the slope at the sampling points was determined using a clinometer. The air temperature and relative humidity were recorded using an ibutton. The grass, shrubs, tree, the number of standing dead trees, and the number of down logs were determined through percentage cover. Microhabitats such as bare ground, woody ground, underwood debris, in water, in trees, in stone/rocks, under stones/rocks, and in holes were searched for the possible presence of amphibians.

The sampling duration depends on the species population curve; when the plateau was reached, or there were no additional species observed, sampling was stopped. The collection of samples was done every 6 pm to 9 pm. We surveyed each sampling site for eight days. Four days were spent for every half of the ten transects laid in every location with eight field workers. Table 1 shows the sampling effort expended during the amphibian survey.

**Table 1** Sampling effort (man-hours) spent during amphibian survey.

| Sampling Stations | Number of field workers | Hours per day | Sampling Days | Sampling Effort Per Season | Sampling Effort for Both Seasons |
|---|---|---|---|---|---|
| Within Mine Site | | | | | |
| Transects 1-5 | 8 | 3 | 4 | 96 | 192 |
| Transects 6-10 | 8 | 3 | 4 | 96 | 192 |
| Outside Mine Site | | | | | |
| Transects 1-5 | 8 | 3 | 4 | 96 | 192 |
| Transects 6-10 | 8 | 3 | 4 | 96 | 192 |
| **Total** | 8 | 3 | 16 | 384 | 768 |

### 2.4 Identification and processing of samples

Field guides and literature on the herpetofauna of the Philippines were used to identify and classify the sampled specimens (Nuñeza et al., 2012; Inger, 1954; Alcala, 1976; Diesmos et al., 2015) and with the help of some experts. With the use of vernier caliper, morphometric measurements were noted such as head length (HL), head breadth (HB), snout length (SL), eye diameter (ED), tympanum distance (TD), snout-vent length (SVL), tibial length (TL) and hind leg (HL). Bodyweight was measured using Pesola spring balance. They were tagged through before they were released back to the field to prevent recapturing and recounting the sample captured specimens. Two voucher specimens, especially those unidentified species, were preserved using 70% ethyl alcohol for 24 hours and then transferred to a 10% formaldehyde solution.

### 2.5 Data analysis

2.5.1 Species diversity and evenness

Determination of biodiversity of a species, which includes species richness (R), relative abundance (RA), Shannon-Weiner (H), and species evenness (E), was computed to determine the exact composition of reptilian species. Paleontological Statistical Software Package (PAST) version 3 (Hammer et al., 2001) was used for data analysis on species' diversity and evenness.

*Species Richness (R)*

The species richness is based solely on the number of species found in the given area and does not reflect the relative dominance of species. The species richness is equal to the number of species collected in the area.

*Relative Abundance (RA)*

Relative abundance is the abundance of species divided by the total abundance of all species combined. The formula for relative abundance is:

$$RA = \frac{n_1}{N} \times 100\%$$

where $n_1$ is the number of individuals in species, and N is the total number of individuals in all species.

*Shannon Diversity Index*

Shannon diversity index was calculated with the formula $H' = -\sum pi \ln pi$, where $pi$ is the proportion of individuals belonging to the $i$th species.

2.5.2 Habitat association and survival envelope

Habitat association of reptilian fauna was analyzed using Canonical Correspondence Analysis (CCA). The analysis is a multivariate direct gradient technique that sets related species directly to a set of environmental variables. It identifies an ecological basis for community ordination by detecting the patterns of variation in community composition that environmental variables can explain. A matrix was constructed comprising with the environmental variable as rows and species abundance as columns. The matrix was then fed to PAST, and CCA was performed.

A diagram was constructed to show the main pattern of variation in the amphibian community composition within and outside the four mining sites in the Caraga region, the Philippines, as accounted by environmental variables and the distribution of species along with each ecological variable. Correlation between the amphibian species and ecological parameters was illustrated as arrows in which longer arrows denote a stronger correlative relationship (ter Braak, 1986).

Survival envelops, niche width, and niche position was presented using boxplot analysis. Species niche width and niche position indicate the habitat preference and habitat tolerance of the species. These were determined using the CCA site scores for each taxon. The median score represents the niche position of the species or the highly preferred habitat type. The box's width shows the preferred habitat of the species, and the whiskers show the extension of the species niche width.

### 2.6 Assessment of endemism and conservation status

Endemism and conservation status of amphibian species were determined based on the IUCN Red List of Threatened Species 2015 and the existing journal (Diesmos et al., 2015; Brown et al., 2012).

## 3 Results

### 3.1 Species accounts

A total of 34 amphibian species, belonging to six families, namely: Bufonidae, Ceratobatrachidae, Dicroglossidae, Megophryidae, Microhylidae, Ranidae, and Rhacophoridae, within and in the surrounding environs of the four key mine sites in Caraga region were found. These species were described as follows:

3.1.1 Family Bufonidae

***Ansonia muelleri*** (Boulenger, 1887) (Fig. 6a)

This species was encountered in both stream and forest surveys. In-stream transects, individuals of this species were found underneath leaf litter and on rocks. This species was only encountered in the large-scale nickel mining area of AMRI in Urbiztondo, Claver, Surigao del Norte. Based on IUCN 2015, it is found in the mountains of Dinagat Island and Mindanao. It is known from several protected areas, including Mount Malindang National Park. It has a morphometrics of HD= 5mm, SL= 6mm, TL= 5mm, HL= 1mm with snout-vent length ranging from 16mm.

***Pelophryne brevipes*** (Peters, 1867) (Fig. 6b)

This species was encountered only outside the mining tenement of Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur. Individuals of this species were found to be arboreal as they were encountered in leaves of trees and shrubs. Usually, this was spotted in the forest with high canopy cover with less light penetration. This small and cryptic species, which is being distinguished by the presence of hourglass marking on the back and a yellow or white stripe or row spots on upper lip from below the eye to below tympanum, has an average snout-vent length of 22 mm; HD = 6 mm; TD = 2 mm; ED = 1 mm; TL = 7 mm.

***Rhinella marina*** (Linnaeus, 1758) (Fig. 6c)

This introduced species (Alcala and Brown, 1998), commonly called Cane toad, was only found outside the mining areas in Bunawan, Agusan del Sur, both within and outside the mining area in Philsaga, Rosario, Agusan del Sur. Individuals of this species were collected under rotting leaves of bananas, and some were encountered near human settlements. This species has a morphometrics of HD= 15.50mm, SL= 14.73mm, TL= 23.38mm, HL= 9.13mm with snout-vent length ranging from 36- 46mm.

3.1.2 Family Ceratobatrachidae

***Platymantis corrugatus*** (Dumeril, 1853) (Fig. 6d)

*Platymantis corrugatus,* the species that is identified by its prominent black facial "mask," was encountered in both stream and forest surveys. Some of its individuals were found on rocks along streams, rotting leaves, and litter on the forest floor. The presence of this species in all sampling sites is consistent with several studies in which it has been considered to exist in various habitats with widespread distribution in the Philippines (Alcala and Brown, 1998; Devan-Song and Brown, 2012). Specimens collected have an average SVL ranging from 18-45mm; HD- 16mm, HB- 17mm, SL- 13mm, ED- 5mm, TD- 2mm, TL- 21mm, and HL- 8mm.

***Platymantis dorsalis*** (Dumeril, 1853) (Fig. 6e)

This species was found in sampling sites except within Philsaga, Rosario, Agusan del Sur and AMRI, Claver, Surigao, Agusan del Sur. Specimens were collected in crevices and holes of trees and even in dense vegetation. Most of its individuals were found on dense shrubs and younger short trees. Even individuals of this species were also observed in the leaf litter on the forest floor. This Philippine endemic species (Alcala and Brown, 1998, 1999; Diesmos and Brown, 2009) has an average snout-vent length of 36 mm, HD = 11 mm, ED = 4 mm, TD = 2 mm, TL = 20 mm.

***Platymantis guentheri*** (Boulenger, 1882) (Fig. 6f)

This endemic and vulnerable species (IUCN, 2015) was encountered in all sampling sites except within and outside the small-scale mine site in San Andres, Bunawan, Agusan del Sur. Most of the individuals of this species were encountered in dense vegetation and rotting leaves and twigs in the forest floor outside the mine site in Masabong, Bayugan 3, Agusan del Sur. This species, distinguished by more or less uniformly dark, lighter (grayish) with dark markings in its dorsum and with a narrow or broad median stripe, or with light dorsolateral stripes, has an average SVL of 33 mm, HD = 10 mm, ED = 4 mm, TD = 2 mm, TL = 17 mm.

***Platymantis rabori*** (Brown, Alcala, Diesmos and Alcala, 1997) (Fig. 6g)

This vulnerable species was only encountered within and outside the mine site in Masabong, Rosario, Agusan del Sur, and outside the mining area in San, Andres, Bunawan, Agusan del Sur. Most of its individuals were found in tree crevices and the leaf litter of the forest floor. Some individuals were found in clumps of grasses and shrubs. Its average morphometric measurements are as follows: SVL- 40mm, HD- 17mm, HB- 18mm, SL- 15mm, ED- 5mm, TD- 3mm, TL- 22mm, and HL- 10mm.


**Fig. 6** Amphibian species belonging to Family Bufonidae (a to c) and family Ceratobatrachidae (d to g) collected in key mine sites of Caraga region. (a) *Ansonia muelleri*, (b) *Pelophryne brevipes*, (c) *Rhinella marina*, (d) *Platymantis corrugatus*, (e) *Platymantis dorsalis*, (f) *Platymantis guentheri* and (g) *Platymantis rabori*.

### 3.1.3 Family Dicroglossidae

***Fejervarya cancrivora*** (Gravenhorst, 1829) (Fig. 7a)

This species was documented within the mine site in San Andres, Bunawan, Agusan del Sur, and outside the mining area in Philsaga, Rosario, Agusan del Sur. This species, which is known to thrive in artificial environments such as rice paddies and even in roadside ditches and puddles (IUCN, 2015), has average morphometrics of HD= 15.50mm, SL= 14.73mm, TL= 23.38mm, HL= 9.13mm with snout-vent length ranging from 36- 46mm.

***Fejervarya limnocharis*** (Fig. 7b)

This species, commonly called Common Pond Frog, was collected only outside the mine site in Philsaga, Rosario, Agusan del Sur near the shallow stream. Collected specimens have an average snout-vent length of 40 mm; HD= 11mm; HB= 12mm; SL= 18 mm; ED= 3 mm; TD =2 mm; TL= 16 mm; HL = 11.

***Fejervarya vittigera*** (Wiegmann, 1835) (Fig. 10c)

*Fejervarya vittigera* occurs on all the major islands in the Philippines and is usually found in anthropogenic habitats such as agricultural areas, ditches, artificial ponds, and lakes (IUCN, 2015). This study found the species found only within and outside the mining sites in San Andres Bunawan, Agusan del Sur, and Philsaga, Rosario, Agusan del Sur.

***Hoplobatracus rugulosus*** (Wiegmann, 1834) (Fig. 7d)

This species, commonly called the Chinese Edible Frog, achieves remarkable population densities in large rice cultivation areas (Brown et al., 2013). This species occurs throughout China and Southeast Asia. It is often found in the rice paddy and the agricultural regions and is known to be a human commensal. Its common name belies the economic importance of this species, which is often farmed and sold as a food resource. This fact most likely contributed to its introduction into the country in the late 1990s (Diesmos et al., 2006). Individuals of this species were recorded outside the mining site in Bunawan and Philsaga, Rosario, Agusan del Sur and have the following average morphometric measurements: SVL- 75mm, HD- 25mm, HB- 28mm, SL- 21mm, ED- 6mm, TD- 5mm, TL- 30mm and HL- 16mm.

***Limnonectes leytensis*** (Boettger, 1893) (Fig. 7e)

Individuals of this species were encountered in all sampling sites except outside the mining area in AMRI, Claver, Surigao del Norte, of which many were found near streams and swamps. Some of its eggs were deposited on vegetation overhanging bodies of water. This widely distributed Philippine endemic species has average morphometrics of the snout-vent length ranging from 28- 50mm, and with average morphometrics of HD= 13.63mm, SL= 12.10mm, TL= 21.48mm, HL= 9.35mm. This species is abundant next to *Limnonectes magnus* in all sampling sites.

***Limnonectes magnus*** (Stejneger, 1909) (Fig. 7f)

This species, commonly called the Philippine Giant Frog, is deemed near-threatened by the IUCN (2015). However, this species was found to be abundant in all mining sites. Albeit this species is deemed near-threatened globally, its abundance can be explained by the fact that data sets of amphibians are tentative as herpetofauna research in Southeast Asia has not received the degree of attention of mammals birds have had. With incomplete data set, determining which species is abundant or not is fraught with uncertainty. In many cases, amphibians are highly restricted in their distribution. Still, they may be locally abundant where they occur and are not found in nearby areas of apparently equivalent habitat by researchers specifically looking for them (Das and van Dijk, 2013). Some individuals of this species were found on stones above free-flowing water in streams, and some were found burrowing along stream beds. This burrowing behavior indicates the suitability of the substrate for burrowing, ensuring the survival of the animal ((Hoffman and Katz, 1989). Some were also encountered in shallow streams with suspended leaves and branches of trees. This species has an SVL ranging from 20- 85mm. The average morphometrics of the species were the following; HD= 16.74mm, SL= 14.78mm, TL= 23.16mm, HL= 10.24mm.

***Limnonectes parvus*** (Taylor, 1920) (Fig. 7g)

Of the 15 individuals documented in the study area, ten of which were found outside the mining area n Masabong, Bayugan 3, Rosario, Agusan del Sur, and the other five individuals were spotted within the mine sites in Philsaga, Rosario, ADS, and San Andres, Bunawan, ADS. This Mindanao endemic frog species, apparently absent in non-forested areas (Brown and Diesmos, 2009), was found in dense vegetation near bodies of water (one of the characteristic microhabitats that can be found outside the mining area of Barangay Masabong, Bayugan 3, Rosario, ADS.). This species has an average SVL of 29 mm, HD = 9 mm, ED = 3 mm, TD = 1 mm, TL = 13 mm.

***Occidozyga laevis*** (Gunther, 1858) (Fig. 7h)

*Occidozyga laevis,* commonly called Small-Headed Frog (IUCN, 2015) was sighted in all sampling sites. This species was frequently sighted in muddy water. This species is active both diurnally and nocturnally. They are primarily aquatic, submersing their entire body in the water except for its snout and eyes (Alcala and Brown, 1998), which has average morphometrics of HD= 18.37mm, SL= 16.63mm, TL= 29.42mm, HL= 11.63mm with snout-vent length ranging from 46- 79mm.

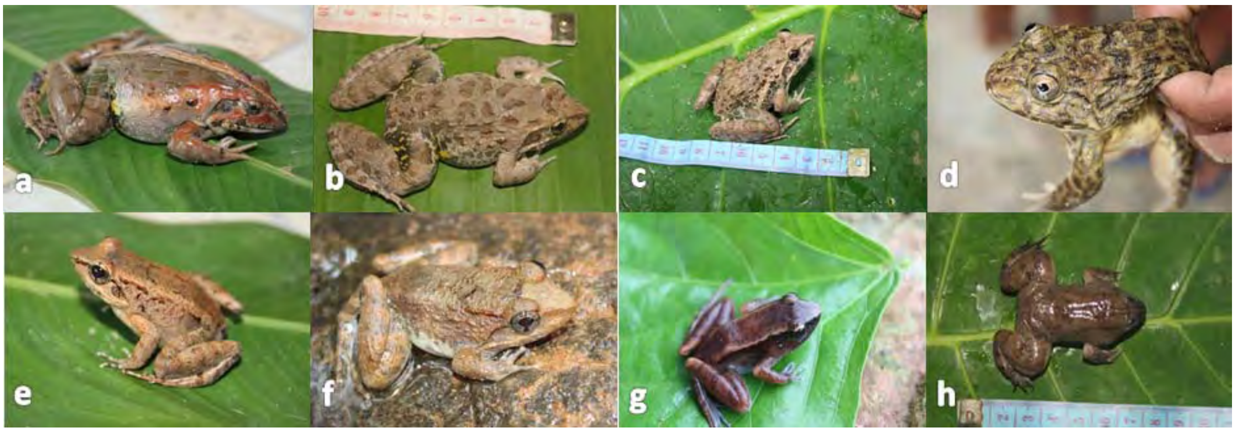


**Fig. 7** Amphibian species belonging to family Dicroglossidae collected in key mine sites in Caraga region, Philippines. (a) *Fejervarya cancrivora*, (b) *Fejervarya limnocharis*, (c) *Fejervarya vittegera*, (d) *Hoplobatrachus rugulosus*, (e) *Limnonectes leytensis*, (f) *Limnonectes magnus*, (g) *Limnonectes parvus* and (h) *Occidozyga laevis*.

3.1.4 Family Megophryidae

***Leptobrachium lumadorum*** (Brown et al., 2009) (Fig. 8a)

*Leptobrachium lumadorum* was spotted in all mining sites except in Philsaga, Rosario, ADS. Only a few individuals of this not assessed species, in terms of its conservation status by the IUCN, were sighted in the study area. Some individuals were found in the forest leaf –litter and two individuals were spotted near streams with submerged dead leaves and twigs of trees. It has an average morphometrics of SVL = 39.1- 65.1 mm; HL =0.39 – 0.44 mm; TL =0.33 mm.

***Megophrys stejnegeri*** (Taylor, 1920) (Fig. 8b)

This species is commonly called Mindanao Horned Frog and is considered Mindanao endemic (IUCN, 2015). It was sighted in all sampling sites and was frequently spotted on the forest floor in leaf litter. It has an average morphometrics of HD= 19.25mm, SL= 13.0mm, TL= 17.5mm, HL=11.63mm with snout-vent length ranging from 46- 77mm.

**Fig. 8** Amphibian species belonging to family Megophryidae collected in the key mine sites in the Caraga region. (a) *Leptobrachium lumadorum* and (b) *Megophrys stejnegeri*.

3.1.5 Family Microhylidae

***Chaperina fusca*** (Mocquard, 1892)(Fig. 9a)

This species, which is a brownish or blackish surface with small and little cream spots (Nuñeza et al., 2010), was encountered outside the mine sites of the sampling areas except in the large-scale nickel mining site in AMRI, Urbiztondo, Claver, Surigao del Norte. Specimens of this species were spotted in tree holes and dry stream beds. Its average morphometrics: SVL- 20mm, HD- 7mm, HB- 8mm, SL- m4m, ED- 1mm, TD- 1mm, TL- 10mm and HL- 5mm.

***Kalophrynus pleurostigma*** (Tschudi, 1838) (Fig. 9b)

*Kalophrynus pleurostigma*, or commonly called Black-spotted Narrow-mouthed Frog(IUCN, is a medium-sized frog with a narrow head and pointed snout; reddish-brown to black, with a light mid-dorsal stripe running from the groin to the tip of the snout (IUCN, 2015). It was sighted in all sampling sites and usually encountered on rotting leaves and branches of trees. It has an average morphometrics of HD= 13.95mm, SL= 8.74mm, TL= 21.0mm, HL= 9.47mm with snout-vent length ranging from 14- 63mm.

***Kaloula conjuncta meridionalis*** (Peters, 1836) (Fig. 9c)

Commonly called the Philippine Narrow- mouth Toad, *Kaloula conjuncta meridionalis* was surveyed outside the mining tenements of Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, and Bunawan, Agusan del Sur. This species was encountered in dry streams and rotting leaves and tree branches. Collected specimen have an average of SVL 27 mm; HD= 15mm; HB= 12 mm; SL= 5 mm; ED= 3 mm; TD= 2 mm; TL 9 mm; HL= 6 mm.

***Kaloula picta*** (Duméril and Bibron, 1841) (Fig. 9d)

*Kaloula picta,* commonly called as Painted Narrow-Mouthed Toad (IUCN, 2015) and primarily terrestrial and nocturnal, hiding by day under stones, logs, or other debris, or in burrows (Inger, 1954), was encountered along streams and near cornfield outside the mining area in Bunawan, Agusan del Sur. It has average morphometrics of SVL- 44.75mm, HD- 15mm, HB- 12mm, SL- 9mm, ED- 4mm, TD- 2mm, TL- 17mm, and HL- 11mm.

***Oreophryne anulata*** (Stejneger, 1908) (Fig. 9e)

*Oreophryne anulata*, commonly called Montane Narrow-Mouthed Frog (IUCN, 2015), is found in humid forests and has secretive habits (Inger, 1954). Individuals of this species were encountered in leaves of young trees and shrubs along forest streams. This was spotted in all sampling sites except in AMRI, Barangay Urbiztondo, Claver, Surigao del Norte. Specimens collected have SVL ranging from 9-16mm, HD- 5mm, HB- 3mm, SL- 2mm, ED- 1mm, TD- 0.92mm, TL- 7mm, and HL- 2mm.

**Fig. 9** Amphibian species belonging to family Microhylidae collected in the key mine sites in Caraga region, Philippines. (a) *Chaperina fusca*, (b) *Kalophrynus pleurostigma*, (c) *Kaloula conjuncta meridionalis*, (d) *Kaloula picta* and (e) *Oreophryne anulata*.

3.1.6 Family Ranidae

***Hylarana grandocula*** (Taylor, 1920) (Fig. 10a)

*Hylarana grandocula,* commonly called Big-eyed Frog which can be distinguished from other Philippine *Rana* by the combination of the following characters: dorsolateral light lines narrow, mid-dorsum with irregular darker mottling, canthus rostralis indistinct, upper eyelid with light line (Inger, 1954), was sighted in all sampling sites. This species, one of the most abundant in the study area along with *Limnonectes magnus* and *Limnonectes leytensis* and *Polypedates leucomystax,* was frequently encountered on rocks projecting above flowing water stream. It has an average morphometrics of HD= 12.54 mm, SL= 12.25mm, TL= 24.6mm, HL= 10.08mm with snout-vent length ranging from 15- 72mm.

***Hylarana nicobariensis*** (Stoliczka, 1870) (Fig. 10b)

*Hylarana nicobariensis*, commonly called Nicobar Island Frog, has *an* elongate snout; the skin of back strongly granular with scattered large tubercles; dorsolateral folds present, usually very prominent; first finger equal to or longer than second; tips of digits expanded into disks with a circumarginal groove. The body is slender, tympanum distinct; no dermal fold from the eye to arm insertion. Tips of fingers and toes expanded. The body color is brown, uniform, or marked with a darker reticulation or spots; lores and temporal region are dark brown, gradually fading posteriorly to tympanum; lips cream or white; legs with dark crossbars (Inger, 1954). This species was encountered along the stream and in rotting leaves and tree twigs and under logs within and outside the mining tenement of Barangay San Andres, Bunawan, Agusan del Sur, and Philsaga, Rosario, ADS. This species has average morphometrics of SVL- 43.30mm, HD- 12mm, HB- 16mm, SL- 12mm, ED- 4mm, TD- 2mm, TL- 22mm, and HL- 9mm.

***Staurois natator*** (Gunther, 1858) (Fig. 10c)

*Staurois natator,* commonly known as the Rock Frog or Mindanao Splash Frog, is characterized by a relatively slender body and long slender legs with fingers and toes that are broadly dilated tips and transverse and circumarginal grooves; toes are completely webbed (Alcala and Brown, 1998). Consistent with the findings of Warguez et al. (2013), many individuals of this species were sighted on leaves of *Alocasia sp.* outside the mine site of Barangay Masabong, Bayugan 3, Rosario, ADS. Some individuals were also found in stones, bare ground, and wood debris on the forest floor. This species has an average snout-vent length of 33 mm; HL = 12 mm; ED = 4 mm; TD = 2 mm; TL = 21 mm.

**Fig. 10** Amphibian species belonging to family Ranidae collected in the key mine sites in Caraga region, Philippines. (a) *Hylarana grandocula*, (b) *Hylarana nicobariensis*, (c) *Staurois natator*.

3.1.7 Family Rhacophoridae

***Nyctixalus spinosus*** (Taylor, 1920) (Fig. 11a)

*Nyctixalus spinosus*, commonly known as Spiny Tree Frog, is a small frog with a reddish-brown color and numerous white tubercles covering the body; cranial and supratympanic crests; slender body and limbs (Alcala and Brown, 1998). This species is endemic to the Philippines and is native to Mindanao, Leyte, Bohol, and Basilan Islands, with an altitudinal range of 500-1,100 m above sea level (Alcala and Brown, 1998; Stuart et al., 2008). It also inhabits the forest floor litter of mountain and lowland rainforests (Alcala and Brown, 1998) and submontane dipterocarp forest (Nuñeza et al., 2010). Individuals of this species were documented only outside the mining areas in Masabong, Rosario, Agusan del Sur, and Bunawan, Agusan del Sur in the forest floor with many decaying leaves and twigs of trees as well as in tree holes and on leaves of shrubs and young shorter trees. This species has an average SVL of 36 mm, HD = 13 mm, ED = 4 mm, TD = 3 mm, TL = 21 mm.

***Philautus acutirostris*** (Peters, 1867) (Fig. 11b)

*Philautus acutirostris,* commonly known as Acute-snouted Tree Frog, has fingers that are not webbed, but toes are webbed; upper eyelids with papillae; usually two prominences between the eyes (Warguez et al., 2013). Fingers free, without rudiment of the web. Above skin is shagreened; papillae on the upper eyelid; usually two prominences between eyes, dorsal surface of limbs with small asperities; belly and ventral surface of thigh coarsely granular. There appear to be two basic dorsal patterns. One consists of an extremely fine reticulation in which the lighter hue predominates, resulting in a green or pinkish-gray tone. The other skin pattern consists of a few obscure dark spots scattered irregularly on a brown or slate ground color (Inger, 1954).

Of the 20 individuals collected in both seasons, 16 were collected outside the mining tenement in Barangay Masabong, Bayugan 3, Rosario, ADS. and only four were sampled outside the mine site Bunawan, Agusan del Sur. Individuals were sighted hopping on leaves of trees and wet tree holes. This species has average morphometrics of SVL- 21mm, HD- 8mm, HB- 9mm, SL- 6mm, ED- 3mm, TD- 1mm, TL- 12mm, and HL- 7mm.

***Philautus leitensis*** (Boulenger, 1897) (Fig. 11d)

This species, commonly called Leyte Tree Frog and found in many parts of Mindanao like Jolo and Basilan (IUCN, 2015), was encountered in tree buttresses, hopping on shrubs' leaves trees. Some individuals were found on the forest floor, along with rotting tree branches and leaves. This was sighted in all mining sites except in Bunawan. Average morphometric measurements of the collected specimens are HD = 9mm, HB = 10mm, SL = 7 mm, ED = 3 mm, TD = 1 mm, SVL = 24mm, TL = 12mm and HL =5mm.

***Philautus poecilus*** (Brown and Alcala, 1994) (Fig. 11e)

This Mindanao endemic species, commonly called mottled tree frog (IUCN, 2015), was only found outside the mining area of Masabong, Bayugan 3, Rosario, ADS. on the leaves of trees and wet tree holes and in the forest leaf-litter. Average morphometric measurements are SVL = 38mm, HL = 17mm, ED = 400mm, TL = 21mm.

***Philautus surdus*** (Peters, 1863) (Fig. 11f)

*Philautus surdus,* commonly known as Luzon Bubble Nest Frog and characterized by having granular body-colored green to brown, is very common in forested areas, even in some disturbed areas adjacent to forests, and can also be found in shrubby vegetation and understory trees (Brown et al., 2012). Individuals of this species were collected outside the mining tenement of Barangay Masabong, Rosario, Agusan del Sur; Philsaga, Rosario, Agusan del Sur, and Bunawan, Agusan del Sur. This was also documented within the mining sites in Bunawan, Agusan del Sur, Philsaga, Rosario, Agusan del Sur, and AMRI, Claver, Surigao del Norte. Some of the individuals were found on the forest floor with thick leaf litter, but most were spotted on leaves of trees and shrubs. This has an average snout-vent length of 21 mm, HL = 6 mm, ED = 2 mm, TD = 1mm, TL = 12 mm.

***Polypedates leucomystax*** (Gravenhorst, 1892) (Fig. 11g)

*Polypedates leucomystax* or commonly called Common tree frog (IUCN, 2015) is documented in all sampling sites and is one of the most abundant species collected in the area. Its individuals were spotted in varied areas, such as fallen banana leaves near the cornfield and rice field outside the mine site in San Andres, Bunawan, ADS. Other individuals were seen on leaves of shrubs and young trees, leaf litter in the forest floor, and even on plants near streams. It has an average morphometrics of HD= 18.37mm, SL= 16.63mm, TL= 29.42mm, HL= 11.63mm with snout-vent length ranging from 46- 79m.

***Rhacophorus appendiculatus*** (Gunther, 1858) (Fig. 11h)

*Rhacophorus appendiculatus,* commonly known as Asiatic Tree Frog (IUCN, 2015), is distinguished with its slender body having dark green spots at its dorsum. Individuals of this species were frequently encountered in leaves of trees and shrubs and tree crevices in all sampling sites. This has an average SVL of 33 mm, HD = 11 mm, ED = 4 mm, TD = 1 mm, HL = 15 mm.

***Rhacophorus bimaculatus*** (Peters, 1867) (Fig. 11i)

*Rhacophorus bimaculatus,* commonly known as Rough-armed Tree Frog and distinguished by having a brownish-colored body and yellowish in the ventral part and with the yellow part above its eyes, was sighted tree ferns and leaves of other trees and shrubs, especially those near the riparian area. Some individuals were spotted on top of fallen logs on the forest floor. This species has an average SVL of 36 mm, HD = 12 mm, ED = 4 mm, TD = 1 mm, TL = 18 mm. This species was collected in all sampling sites.

***Rhacophorus pardalis*** (Günther, 1859) (Fig. 11j)

*Rhacophorus pardalis,* commonly known as Gliding Tree Frog, is a species that has extensively webbed fingers, tips of fingers with very large pads, that of third finger wider than tympanum; the snout is rounded or obtusely pointed; tympanum visible; no dorsolateral fold; body tapering abruptly behind shoulders except in females; head a little broader than long; body color is variable; dorsum (in alcohol) brown or purple, uniform or with a dark cruciform mark or with small light spots; ventrally uniform white or cream; limbs with or without dark crossbars (Inger, 1954). This species was encountered in all sampling sites and was frequently sighted in leaves of ferns and other plants and trees. Some species were also spotted on a thick leaf litter on the forest floor. Its average morphometrics are as follows: SVL- 32.75mm, HD- 11mm, HB- 12mm, SL- 10mm, ED- 4mm, TD- 2mm, TL- 18.5mm and HL- 7.5mm.

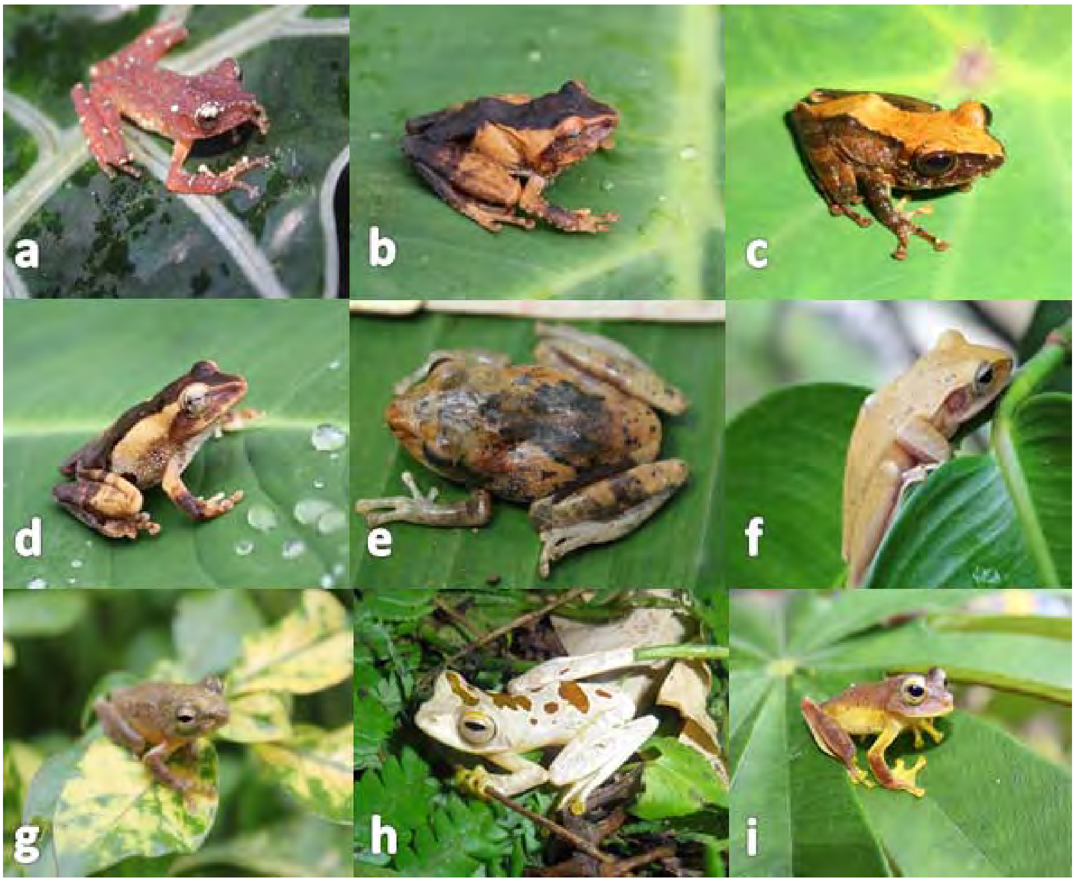


**Fig. 11** Amphibian species belonging to family Rhacophoridae collected in the key mine sites in Caraga region. (a) *Nyctixalus spinosus*, (b) *Philautus acutirostris*, (c) *Philautus leitensis*, (d) *Philautus poecilus*, (e) *Philautus surdus*, (f) *Polypedates leucomystax*, (g) *Rhacophorus appendiculatus*, (h) *Rhacophorus bimaculatus*, (i) *Rhacophorus pardalis*.

### 3.2 Species richness and abundance

Species richness and abundance vary between sites and seasons (Figs. 12, 13). The richness of species shows to be higher outside than within the mining tenement. All of the species documented in the whole study area were also found outside the mine site. This is also true with the abundance of species inside the mine site. Fewer individuals of these anuran species were collected than the surrounding environs of the mining tenement. Temporal variation concerning species richness and abundance was also observed.

The number of species and abundance appeared to be higher during the wet season than in the dry season. One of these surveyed species has been identified only until the genus level, which seemed to belong to the genus Platymantis. The species of this genus were found outside the mining area and near a stream with floating leaves and twigs. The distal parts of its digits are swollen with granular or coarsely brown skin. It has a yellowish line on its head, which appears to be like a crown, and the upper eyelid is colored orange.

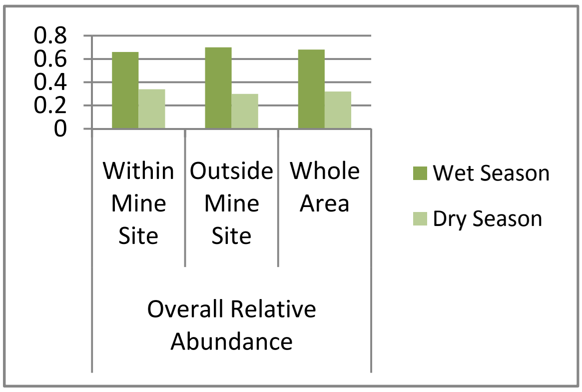


**Fig. 12** Overall relative abundance of the anuran species collected within and outside the small-scale gold mining area in Brgy. Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines.

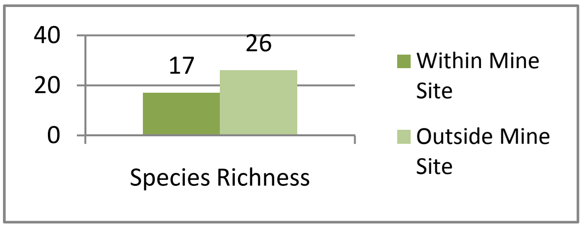


**Fig. 13.** Species richness of anuran species collected within and outside the small-scale gold mining area in Brgy. Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines.

### 3.3 Endemism and conservation status

Of these anuran species, 17 (65.4%) are endemic to the country with 3 (11.5%) species that are solely distributed in Mindanao Faunal Region, namely *L. parvus, M. stejnegeri* and *P. acutirostris* (Table 2). Based on the recent assessment of the International Union for the Conservation of Nature (IUCN) Red Data List, one of these anuran species *l. magnus* has near-threatened conservation status while ten are vulnerable, including *P. guentheri, P. rabori, L. parvus, M. stejnegeri, O. anulata, N. spinosus, P. acutirostris, P. leitensis, P. poecilus* and *R. bimaculatus*. Conversely, others are considered of least concern, and even some having data deficient and not assessed based on the 2015 IUCN Red List. Our survey revealed that the number of endemic species collected outside the mining area is higher than inside the mine site. Of the 17 endemics, seven of these were not encountered within the mining site for both seasons. These include *P. guentheri, P. sp.1, L. parvus L. lumadrom, N. spinosus, P. poecilus,* and *P. surdus* (Table 2).

**Table 2** Anuran profile found within and outside the mining area in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines.

| Taxa | Common Name | Residency Status/ IUCN Status | Presence (/) or Absence (x) | |
|---|---|---|---|---|
| | | | Within Mine Site | Outside Mine Site |
| **Bufonidae** | | | | |
| *Pelophryne brevipes* | Mindanao Toad | NE/LC | √ | √ |
| **Ceratobatrachidae** | | | | |
| *Platymantis corrugatus* | Corrugated Ground Frog | EN/LC | √ | √ |
| *Platymantis dorsalis* | Common Forest Ground Frog | EN/LC | √ | √ |
| *Platymantis guentheri* | Guenther's Forest Frog | EN/VU | X | √ |
| *Platymantis rabori* | Rabor's Forest Frog | EN/VU | √ | √ |

| | | | | |
|---|---|---|---|---|
| *Platymantis sp.* | | EN/NA | X | √ |
| **Dicroglossidae** | | | | |
| *Limnonectes leytensis* | Small Disked Frog | EN/LC | √ | √ |
| *Limnonectes magnus* | Philippine Giant Frog | NE/NT | √ | √ |
| *Limnonectes parvus* | Bunawan Wart Frog | ME/VU | X | √ |
| *Occidozyga laevis* | Common Small-headed Frog | NE/LC | √ | √ |
| **Megophryidae** | | | | |
| *Leptobrachium lumadorum* | | EN/NA | X | √ |
| *Megophrys stejnegeri* | Mindanao Horned Frog | ME/VU | √ | √ |
| **Microhylidae** | | | | |
| *Chaperina fusca* | Spotted-belly Narrow-mouthed Frog | NE/LC | X | √ |
| *Kalophrynus pleurostigma* | Black-spotted Narrow mouthed Frog | NE/LC | √ | √ |
| *Oreophryne anulata* | Montane Narrow-mouthed Frog | EN/VU | √ | √ |
| **Ranidae** | | | | |
| *Hylarana grandocula* | | EN/LC | √ | √ |
| *Staurois natator* | Mindanao Splash Frog; Rock Frog | NE/LC | √ | √ |
| **Rhacophoridae** | | | | |
| *Nyctixalus spinosus* | Spiny Tree Frog | EN/VU | X | √ |
| *Philautus acutirostris* | Acute-snouted Tree Frog | ME/VU | √ | √ |
| *Philautus leitensis* | Leyte Tree Frog | EN/VU | √ | √ |
| *Philautus poecilus* | Mottled tree frog | EN/VU | X | √ |
| *Philautus surdus* | Common forest tree frog | EN/LC | X | √ |
| *Polypedates leucomystax* | White-lipped Tree Frog | NE/LC | √ | √ |
| *Rhacophorus appendiculatus* | Rough-armed Tree frog | NE/LC | X | √ |
| *Rhacophorus bimaculatus* | Mindanao Flying Frog | EN/VU | √ | √ |
| *Rhacophorus pardalis* | Harlequin Tree Frog | NE/LC | √ | √ |

Residency Status: NE – Non-endemic, EN – Endemic, ME – Mindanao endemic
Conservation Status: LC – Least Concern, VU – Vulnerable, NT = Near Threatened, NA – Not Assessed, DD – Data Deficient

### 3.4 Species diversity

Simpson's and Shannon's diversity indices determined higher anuran diversity outside the mining area than inside the mine site (Table 3). Concerning the anuran diversity between seasons, results revealed that anurans are more diverse and are evenly distributed during the wet season than in the dry season.

**Table 3** Diversity of anurans species collected within and outside the mining tenement in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines.

| | Within Mining Area | | | Outside Mining Area | | | Overall Wet Season | Overall Dry Season | Whole Area |
|---|---|---|---|---|---|---|---|---|---|
| | Wet Season | Dry Season | Total | Wet Season | Dry Season | Total | | | |
| Taxa S | 16 | 14 | 16 | 26 | 22 | 26 | 26 | 22 | 26 |
| Individuals | 242 | 125 | 367 | 511 | 224 | 735 | 753 | 349 | 1102 |
| Dominance D | 0.09139 | 0.119 | 0.09724 | 0.06716 | 0.08773 | 0.06997 | 0.0722 | 0.09441 | 0.07717 |
| Simpson 1-D | 0.9086 | 0.881 | 0.9028 | 0.9328 | 0.9123 | 0.93 | 0.9278 | 0.9056 | 0.92228 |
| Hannon H | 2.551 | 2.378 | 2.51 | 2.936 | 2.726 | 2.909 | 2.869 | 2.657 | 2.825 |
| Evenness | 0.801 | 0.7702 | 0.7687 | 0.7249 | 0.6943 | 0.7052 | 0.6775 | 0.6477 | 0.6483 |

### 3.5 Habitat association and survival envelope

Canonical Correspondence Analysis (CCA) was used to show the habitat association of the collected anuran species using eight environmental variables such as % grasses, % shrubs, % trees, humidity, elevation, temperature, number of dead standing trees, and amount of fallen logs. Vectors represent these environmental variables. The length of the vector indicates the relative weight of a given variable in the ordination, while its direction indicates the correlation of the variable with the axis. The vectors in Fig. 14 accounted for a 43.46% variation of the 26 species of anurans concerning the eight environmental variables, the sum of all eigenvalues being 0.18. On the other hand, the vectors accounted for a 15% variation of the surveyed anuran species in the study area has a sum of eigenvalues of 0.06. The vectors of habitat variables on the left side of the axis indicate a forest habitat, as shown by the increasing percentage of trees with high humidity and elevation. The vectors on the right side describe remnants of a forest area as evidenced by standing dead trees and fallen logs, and an increasing percentage of grasses. This may represent a once forested area cleared out because of timber cutting or forest conversion into cultivated land. This is also supported by the increasing temperature, which is a characteristic of an open or a non-forest area.

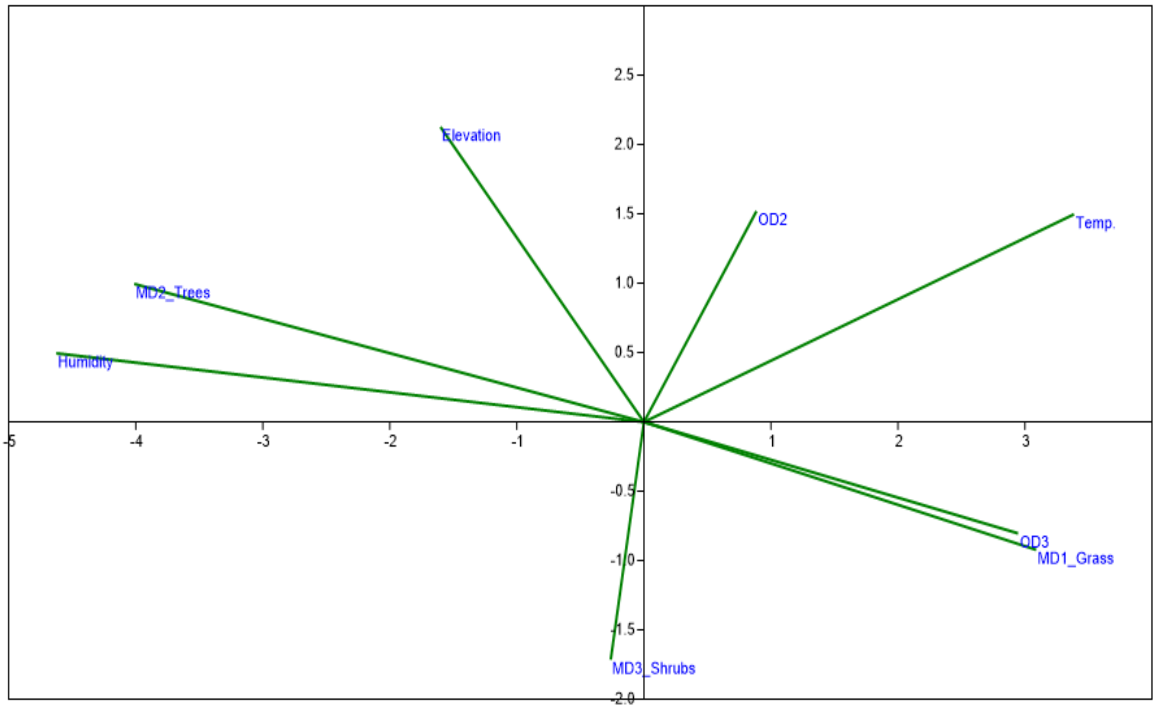


**Fig. 14** Ordination of all anuran species' habitat variables within and outside the mining tenement in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines. Legend: MD1 = percentage of grasses, MD2 = percentage of trees, MD3= percentage of shrubs, OD2 = number of standing dead trees, OD3 = number of fallen dead trees; Temp. = temperature.

Fig. 15 shows the position of 26 amphibian species centroids. From this, the habitat preferences of the 26 anuran species can be depicted. Most of the anurans centroids (represented by dots) are positioned on the left side of the axis, indicating a preponderance of this anuran community with forest habitat. In contrast, the only anuran species which leans itself on the right side of the axis is tolerant of cultivation and anthropogenic disturbances. Species centroids positioned near the center of the axis are encountered at the interface between a forest and a non-forest area.

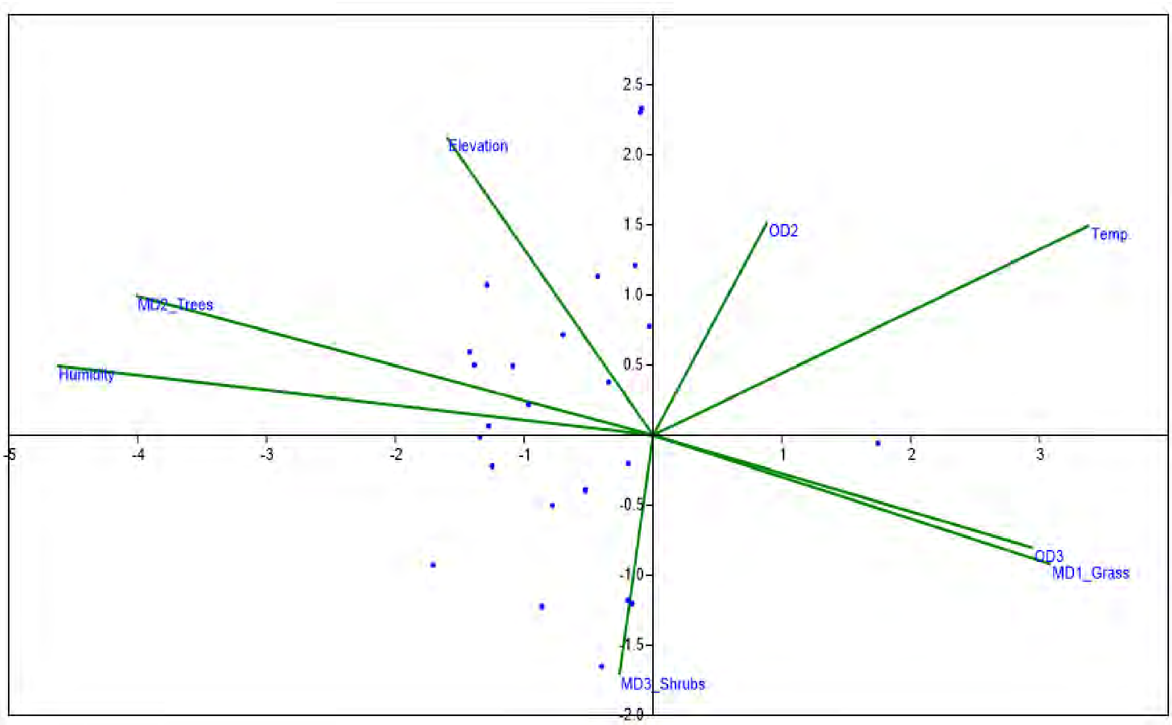


**Fig. 15** Position of anuran species (represented by dots) collected within and outside the mining tenement in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines in relation to the nine environmental covariates. Legend: MD1 = percentage of grasses, MD2 = percentage of trees, MD3= percentage of shrubs, OD2 = number of standing dead trees, OD3 = number of fallen dead trees, Temp. = temperature.

The superimposition of the habitat parameter vectors, and the 26 species centroids, is presented in Fig. 16. From this, the habitat preferences of the 26 anuran species can be depicted. Species positioned on the left side of the vertical axis are strongly correlated with forest habitat, as evidenced by their association with environmental parameters inherent to forest habitat, such as increased percentage of trees, high humidity, and usually in elevated areas.

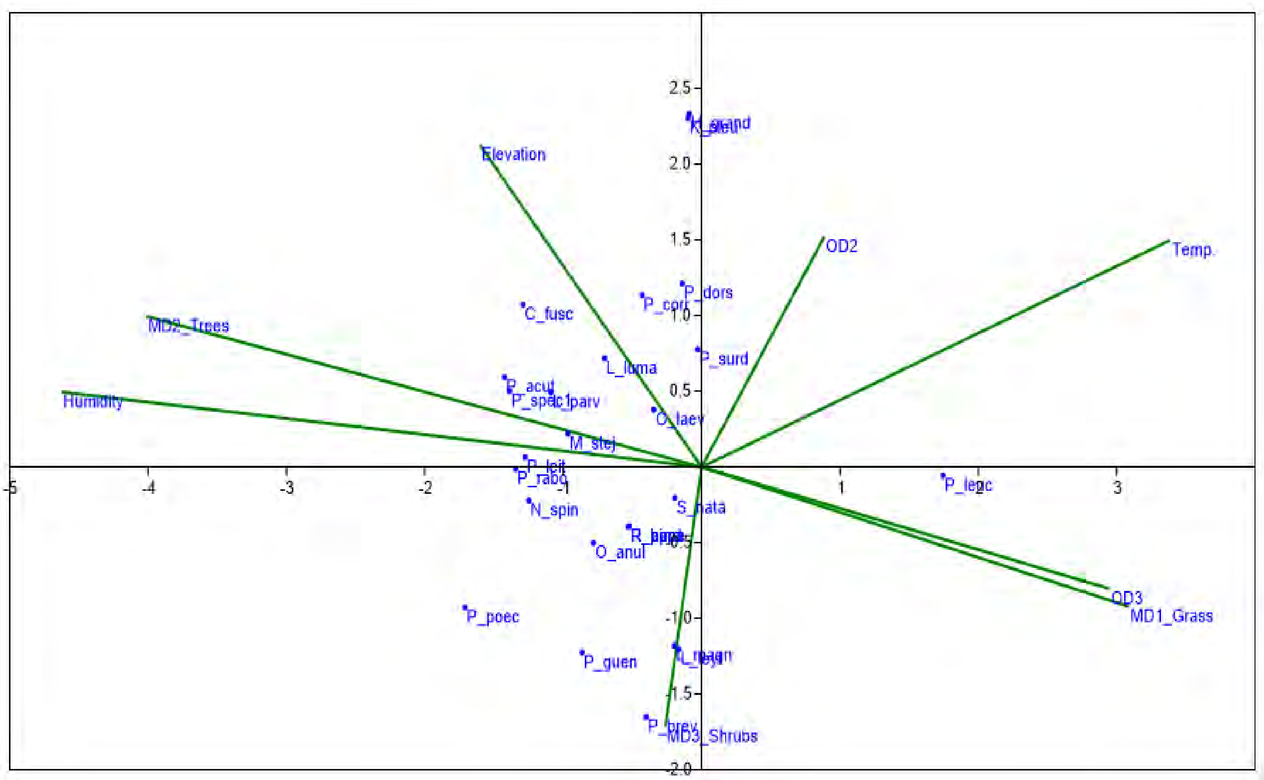


**Fig. 16** Superimposition of the environmental parameter vectors with the 26 anuran species collected within and outside the mine site in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines. Legend: P_ poec = *Philautus poecilus*, P_guen = *Platymantis guentheri*, P_ acut = *Philautus acutirostris*, C_fusc = *Chaperina fusca*, L_parv = *Limnonectes parvus*, P_brev = *Pelophryne brevipes*, P_leit = *Philautus leitensis*, N_spin = *Nyctixalus spinosus*, R_bima = *Rhacophorus bimaculatus*, M_stej = *Megophrys stejnegeri*, O_anul = *Oreophryne anulata*, P_rabo = *Platymantis rabori*, P_spec = *Platymantis sp. 1*, L_luma = *Leptobrachium lumadorum*, P_surd = *Philautus surdus*, R_pard = *Rhacophorus pardalis*, P_dors, *Platymantis dorsalis*, P_corr = *Platymantis corrugatus*, K_pleu = *Kalophrynus pleurostigma*, R_appe = *Rhacophorus appendiculatus*, S_nata = *Staurois natator*, O_laev =*Occidozyga laevis*, H_gran = *Hylarana grandocula*, L_magn = *Limnonectes magnus*, L_leyt = *Limnonectes leytensis* and P_Leuc = *Polypedates leucomystax;* MD1 = percentage of grasses, MD2 = percentage of trees, MD3= percentage of shrubs, OD2 = number of standing dead trees, OD3 = number of fallen dead trees; Temp. = temperature.

Results of CCA analysis are being supported by the boxplot analysis (Fig. 17), which shows not only the niche positions of the anuran species but also their niche widths or range of survival. Consistent with the CCA results, anuran species such as *P. poecilus, P. acutirostris, L. parvus, P. guentheri, P. brevipes, C. fusca, O. anulata, P. sp. 1, M. stejnegeri, P. rabori, R. bimaculatus, L. lumadorum, P. leitensis, R. appendiculatus, N. spinosus, R. pardalis, P. dorsalis* and *O. laevis* have niche positions strictly towards the forest. Most individuals of the species like *L. magnus, S. natator, P. corrugatus, L. leytensis, K. pleurostigma, P. surdus,* and *H. grandocula* were encountered at the interface between forest and non-forest areas; however, some were collected in the interface between forest and non-forest area. Moreover, P. *leucomystax* is the lone species that displaced itself towards the non-forest area, albeit some of these species are also encountered in the interface and in the forest.

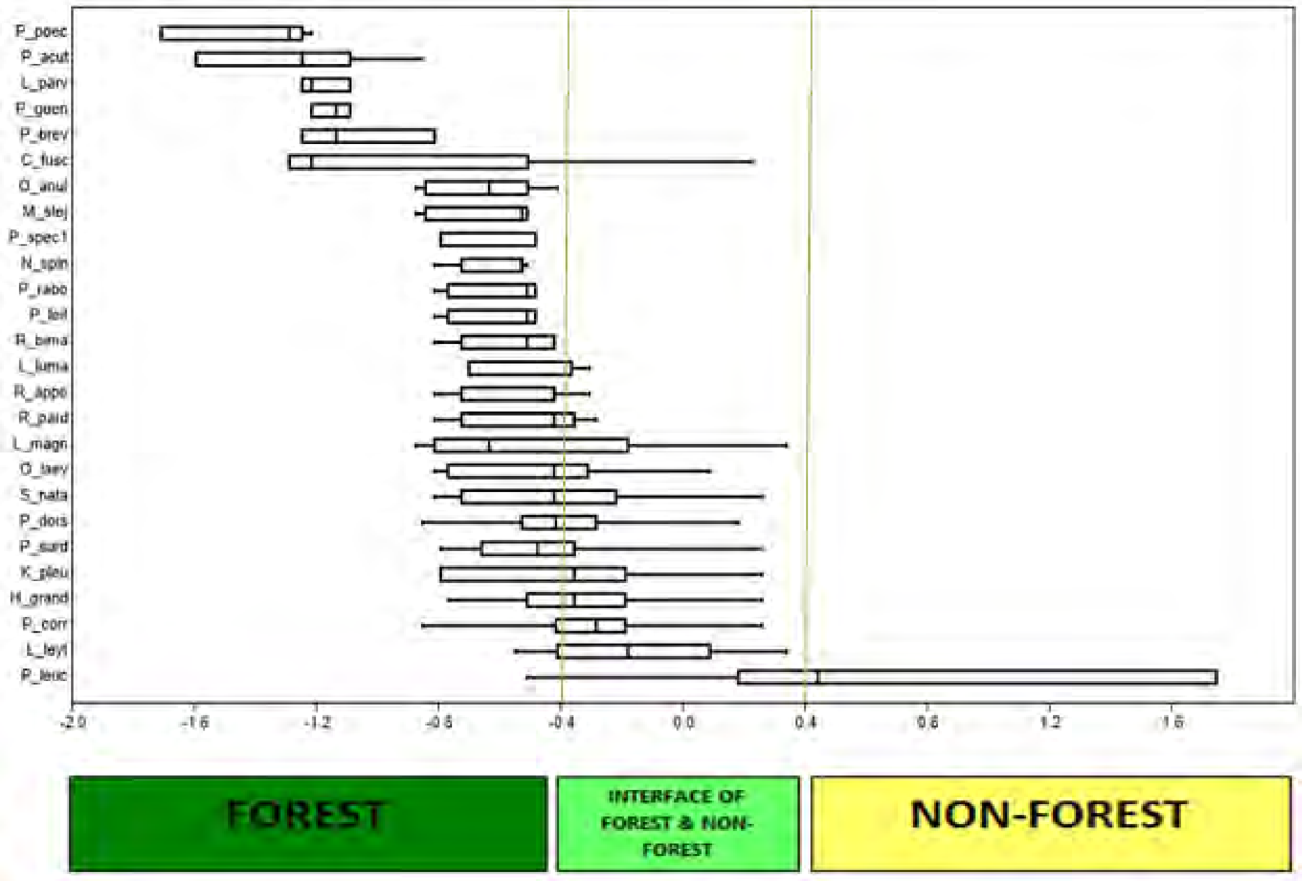


**Fig. 17** Box and whisker plots showing the niche widths and niche positions of the 26 anuran species collected within and outside the mine site in Barangay Masabong, Bayugan 3, Rosario, Agusan del Sur, Philippines. Legend: P_ poec = *Philautus poecilus*, P_guen = *Platymantis guentheri*, P_ acut = *Philautus acutirostris*, C_fusc = *Chaperina fusca*, L_parv = *Limnonectes parvus*, P_brev = *Pelophryne brevipes*, P_leit = *Philautus leitensis*, N_spin = *Nyctixalus spinosus*, R_bima = *Rhacophorus bimaculatus*, M_stej = *Megophrys stejnegeri*, O_anul = *Oreophryne anulata*, P_rabo = *Platymantis rabori*, P_spec = *Platymantis sp. 1*, L_luma = *Leptobrachium lumadorum*, P_surd = *Philautus surdus*, R_pard = *Rhacophorus pardalis*, P_dors, *Platymantis dorsalis*, P_corr = *Platymantis corrugatus*, K_pleu = *Kalophrynus pleurostigma*, R_appe = *Rhacophorus appendiculatus*, S_nata = *Staurois natator*, O_laev =*Occidozyga laevis*, H_gran = *Hylarana grandocula*, L_magn = *Limnonectes magnus*, L_leyt = *Limnonectes leytensis* and P_Leuc = *Polypedates leucomystax.*

Still, regarding Fig. 17, the survival envelopes of almost all forest species are narrow, as shown by their narrow boxplots. Of noteworthy are the *P. guentheri* and the Mindanao endemic *L. parvus*, with the shortest niche widths.

The species richness, abundance, and diversity are higher outside than within the mine site. Although specific forest patches outside the mining area were subjected to slash-and-burn and converted to falcata plantation, the area is still thickly forested compared to the mine to that of the inside of the mining tenement. The high vertical heterogeneity outside the mine site due to different trees, characteristic of forest habitats, would support the variability of amphibian species. The closed canopy cover and native vegetation outside the mine site are favorable to amphibians as it offers a more humid environment necessary for their survival (Petrov, 2007). The presence of native vegetation in a forest area allows most frog species to increasingly survive since amphibians are poikilothermic or cold-blooded organisms whose body temperature depends on environmental temperature (Lemckert, 2004; Lemckert et al., 2004, 2007; Kardong, 1995).

Moreover, the abundance of decaying fallen logs, tree branches and leaves affect populations of amphibians by providing them essential retreat sites, increased diversity, and abundance of invertebrate and vertebrate prey for many species of amphibians (Dorcas and Gibbons, 2008). On the other hand, the indiscriminate cutting of trees to be used as timber stands in the mining portals resulted in the landscape change in the area. This is due to mine tunneling are compounding factors that caused habitat loss for many anuran species, predominantly present in lowland dipterocarp forest (Fernandez and Nuneza, 2007). The pollution of streams from mine tailings would also explain the lesser species richness, abundance, and diversity within the mining area (Mallari et al., 2001) as amphibians are so sensitive and vulnerable to slight changes in the environment, making them excellent bioindicators (Welsh and Ollivier, 1998; Sheridan and Olson, 2003). Also, the increased number of human settlers, the mining operators, and their family members within the mining sites, especially for two small-scale mining areas (Masabong and Bunawan areas), increased habitat disturbances to the amphibians dramatically affects their abundance, richness, and diversity.

The temporal variation of species richness and abundance observed during the wet season having higher species richness and abundance than during the dry season could be correlated by the behavioral pattern exhibited by the amphibians during the summer season. In summer, hot, dry weather can be stressful for amphibians, and often during such times, they may go dormant; however, now, instead of having hibernation, they performed estivation. When some amphibians estivate, they move underground, where it is more relaxed and more humid. During estivation, an amphibian’s breathing, heart rate, and metabolic processes dramatically slow down (Conrad, 2010). This decreases the amphibians' need for water; thus, they tend to hide to avoid desiccation. The study of Jofre *et al.* (2010) from the central region of Argentina shows that the highest relative abundance of anurans was detected in the area that provides stable food and refuges having permanent reservoirs from precipitation, which is experienced during the wet season. High rainfall would ensure the steady supply of water in pools, streams, and rivers, which are crucial for the aquatic amphibians undergoing indirect development or complete metamorphosis, specifically those laying eggs (Kardong, 1995).

The pattern of niche position or habitat association of the 34 anuran species revealed that many of the anuran species displaced themselves in the forest habitat with some interface between the forest and non-forest area or open area and others in the forest non-forest area. However, forest-dwelling species extend their survival envelopes to the interface between forest and non-forest fields, and there are even interface associates that extend themselves in both forest and non-forest areas. Other species having an optimum niche in the non-forest area extend their survival envelope towards the forest interface and even the forest (Fig. 25). Hence, we suggest five groups of these anuran species based on the extent of their niche position as follows: forest-dependent, forest but extending to the forest-nonforest interface, forest-nonforest interface but extending to forest and non-forest, non-forest but extending to the forest-nonforest interface, and non-forest extending to the forest area (Table 6).

**Table 6** Summary of niche positions and niche widths of the 34 anuran species found in the sampling mine sites in Caraga region, Philippines.

| **Forest-dependent species** | **Forest species extending to forest interface** | **Forest species extending to forest and non-forest** | **Non-forest species extending to forest interface** | **Non-forest extending to forest** |
|---|---|---|---|---|
| *Philautus poecilus* | *Rhacoporus bimaculatus* | *Platymantis corrugatus* | *Hoplobatrachus rugulosus* | *Polypedates leucomystax* |
| *Phelophryne brevipes* | *Philautus surdud* | *Occidozyga laevis* | *Fejervarya limnocharis* | |

| | | | | |
|---|---|---|---|---|
| *Rachoporus acutirostris* | *Leptobrachium lumadorum* | *Hyalarana grandocula* | *Hylarana nicobariensis* | |
| *Platymantis rabori* | *Racophorus pardalis* | *Platymantis dorsalis* | *Fejervarya vittegera* | |
| *Nyctixalus spinosus* | *Staurus natator* | *Kalophrynus pleurostigma* | *Kaloula picta* | |
| *Philautus leitensis* | *Platymantis guentheri* | *Limnonects leytensis* | *Kaloula conjuncta meridionalis* | |
| *Ansonia muelleri* | *Rhacophorus bimaculatus* | *Limnonects magnus* | *Fejervarya cancrivora* | |
| *Oreophryne anulata* | *Chaperina fusca* | | *Rhinella marina* | |
| *Megophrys stejnegeri* | | | | |
| *Limnonectes parvus* | | | | |

Based on boxplot analysis, all of the globally threatened species, except for *Platymantis guentheri* and *Rhacophorus bimaculatus,* extend their survival range to the forest interface. The *L. magnus,* which orients itself in the forest interface and reaches its occupancy in both forest and non-forest habitats, has its niches positioned in the forest area and has narrow niche widths or survival envelopes. The inability of these globally threatened species to utilize both the forest-nonforest interface and the non-forest site could be the reason for the decline of their populations. This observation is congruent with the study of Lloyd et al. (2008), who worked on bird communities in the *Polylepis* woodlands and its surrounding matrix habitats in Cordillera Vilcanota, Southern Peru. They were able to show that forest specialist bird species failed to extend their niche width to either forest-matrix interface or matrix habitat. Hence, they suggested that this is the cause of the population declines and local extinction of these forest bird specialists. Furthermore, the narrow niche widths of the globally threatened forest specialists with a restricted range of habitat occupancy being endemic species might be a compounding factor of their population declines.

Forest species extend their habitat occupancy to the forest interface, and the forest interface species grow their ecological niche to forest and nonforest areas. They were found in the forest floor or the streams of disturbed lower montane and lowland forests like *P. dorsalis, K. pleurostigma, L. leytensis, Philautus surdus* and *H. grandocula* (IUCN, 2015). The wide niche widths of these species, utilizing both the forest and the forest interface, would account for why they are not faced on the brink of a population crash. Of noteworthy here is the extension of the niche width of the forest interface-associated and near-threatened species *L. magnus* to both forest and non-forest areas, as evidenced by the expansion of the whiskers of its boxplot to both nonforest and forest habitats. The increased habitat occupancy of this species might explain why locally, it is one of the abundant species collected in the area. However, this observation seems contradictory because, globally, this species is deemed near-threatened, meaning its population declines (IUCN, 2015). Population decline of this species may be because of the significant widespread habitat loss through much of its range and over-harvesting since this is an edible kind of amphibian. But, according to Das and van Dijk (2013), data sets of amphibians are tentative as herpetofauna research in Southeast Asia has not received the degree of attention that mammals and birds have had. With incomplete data set, determining which species is abundant or not is fraught with uncertainty. In many cases, amphibians are highly restricted in their distribution but may be locally abundant and are not found in nearby areas with equivalent habitats by researchers explicitly looking for them.

The presence of globally threatened and endemic species, having narrow niche positions and widths, in the area implies that some conservation efforts must be in place. With the ongoing mining explorations and the presence of other anthropogenic disturbances in the area, undoubtedly, these species, faced with population declines globally and with restricted distributional range, are at risk. Fragmentation of forests due to mining activities would possibly displace the arboreal anuran species from their habitats. Thus, responsible mining must be strictly implemented that would spare these endemic species in the area.

## 4 Conclusion

Because of biphasic lifestyle and membranous and permeable skin, amphibians provide an early warning of environmental deterioration. Diversity, endemism, habitat associations, and survival envelopes were assessed outside of the selected mining sites. Of the thirty-four amphibian species observed, four of the 15 endemic species can be found only in Mindanao; eleven species were vulnerable and one near-threatened. Endemism and species diversity were observed to be higher outside the mining area due to habitat loss and forest fragmentation within the mine area.

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