DISTRIBUTION AND DIVERSITY PATTERNS OF AMPHIBIAN SPECIES IN THE RAJAH SIKATUNA PROTECTED LANDSCAPE, BOHOL, PHILIPPINES

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Abstract

This recent study conducted at Rajah Sikatuna Protected Landscape, Bohol, Philippines (RSPL) from August to October 2019 resulted to a total of 17 amphibian species belonging to 7 families; of these species, two (2) are near threatened, 11 are Philippine endemics, five (5) are native, and one (1) introduced/non-native. Barangay Bugsoc had the highest diversity H (2.09) as well as species richness (10); Barangay Omjon also had a species richness of 10, both of these areas are forested and riparian areas. Abundance of the number of individuals and number of species geared towards mixed vegetation forest and riparian areas at elevation ranging from 400-600 masl. High species diversity, evenness and richness (Shannon-Weiner, Shannon evenness and Menhinick richness indices) were observed on areas with minimal anthropogenic disturbance. The distribution pattern can be linked to the influence of resource accessibility and microclimatic conditions available for direct utilization by the species. Conversely, areas with high disturbance, such as agricultural and grassland areas, showed high dominance of *Rhinella marina*, an introduced species.

***Key words*:** Anurans; Central Visayas; Elevational gradient GIS map; Philippines.

INTRODUCTION

The Philippine Archipelago is recognized as one of the most important centers of herpetofaunal diversity in Southeast Asia (Diesmos *et al.* 2002). To date, 112 species of Philippine amphibians have been discovered with at least 80% endemic to the archipelago (Diesmos *et al.* 2015). The highly diverse and endemic herpetological fauna of the Philippine Islands faces many threats due to habitat modification and loss, natural catastrophes, invasive species, and hunting for food (Sodhi *et al.* 2004). The number of Philippine species currently stands at 26, but dozens of newly discovered species are still awaiting description (Diesmos *et al.* 2002).

Anuran diversity studies have previously focused in Luzon, Mindoro, Palawan and Central Philippines (Alcala and Brown 1998). Due to the Philippines' archipelagic nature, all areas of the island chain must be studied as habitats and species distribution will vary greatly throughout the country. Additionally, in depth research, beyond baseline information about the composition and presence or absence of these species should be conducted for a better understanding of anurans and their conservation.

The present study investigated the distribution and diversity patterns of amphibians in the selected barangays of Rajah Sikatuna Protected Landscape (RSPL). Additionally, habitat type and elevation were analyzed for species habitat preference. These results will serve as additional and updated information for conservation management stakeholders to utilize in strengthening their future conservation efforts.

METERIAL AND METHODS

Survey areas

Rajah Sikatuna Protected Landscape is a protected area of forested limestone hills, grasslands and natural springs in the island province of Bohol in the Central Visayas region of the Philippines. At

10,452.7 hectares, the RSPL is the largest tract of natural habitat in Bohol. However, not all of the RSPL is pristine forest; 60% of the area is limestone forest and 15% grassland, 5% plantations and 10% permanent agricultural areas (Bird Life International 2014, Birding 2 Asia 2014)**.** The climate classification falls within type IV wherein rainfall is more or less evenly distributed throughout the year with no dry season (Lantican 2001) and with an annual rainfall of 3,756 mm (en.climate-data.org 2019)**.**

Field surveys were conducted between August and September 2019. Survey areas included six Barangays within RSPL: Bugsoc, Cabacnitan, Cambuyo, Nan-od, Omjon and Villasuerte (Fig. 1). Bugsoc, located in the municipality of Sierra Bullones**,** is dominated by dipterocarps and some indigenous species, but exotic species like *Swietenia macrophylla* are present in this site along the river. Cabacnitan, located in the municipality of Batuan, is primarily Dipterocarpaceae species which provide lots of leaf and litters. Cambuyo, located in the municipality of Garcia Hernandez, has been observed anthropogenic disturbances, such as cut down *Swietenia macrophylla* along the forest edges. Nan-od, located in the municipality of Sierra Bullones, has areas of stagnant rivers and swamp with Dipterocarps species and understorey layer consisting of *Swietenia macrophylla* as dominant vegetation. Omjon, located in the municipality of Valencia, is riparian vegetation dominated by the dipterocarp species. Lastly, Villasuerte, located in the municipality of Bilar, is dominated by dipterocarp, shrubs and fern like *Diplazium esculentum* and many plant litters as well as caves with water.

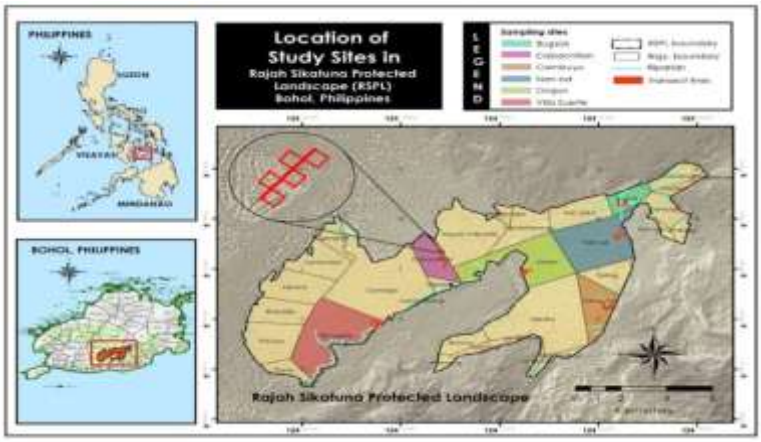

Fig. 1. Map of Rajah Sikatuna Protected Landscape, Bohol, Philippines showing the established transect lines

Sampling Method

Three transect lines were established for each survey areas (Fig. 1). Transect lines were positioned parallel to the existing trails and perpendicular to rivers. The length of transect line is 100 meters with an interval distance between each transect line at 100 meters. A 20×20 meter quadrat was established along each transect line. Amphibians were collected in the early morning, 06:00-09:00, and in the evening, 19:00-22:00 (Warguez *et al.* 2013). The visual encounter survey was employed to search high potential areas, such as on the surface and under rocks, logs, litters, trees, and other remains along the transect lines, throughout the survey areas. All objects displaced from the area were returned back to their original positions to avoid further disturbance the habitats.

Habitat type was based on the classification of Fernando (2009) who considered the physical characteristics of habitat, vegetation structure and physiognomy in the classification.

Species Collection and Identification

Initial identification was completed using the field guide from Diesmos and Brown 2011) and IUCN List of Threatened Species available at (IUCN 2018). To support identification, each specimen collected was photographed and measured for its morphometric using the standard measurements adopted from Haribon Foundation Guidelines for Amphibians and Reptiles Survey (2004). Photos and morphometric measurements were sent to Philippine National Museum for confirmation and verification. The specimens which could not be confirmed as species in the field were collected under Wildlife Gratuitous Permit no. VII-2019-04 issued by the Department of Environment and Natural Resources (DENR) Region VII. Standard preservation techniques were employed (Heyer *et al.* 1994). The specimens were stored to be identified at a later date.

Computation of Diversity Indices

Species Diversity: The Shannon-Wiener diversity index (H) was used to assess the diversity of amphibians. The proportion of species 1 relative to the total number of species (Pi) was calculated and multiplied by the natural log of this proportion (LNPi) and the resulting product was summed across species (Magurran 1984).

$$H' = -\sum(Pi * LNPi)$$

Dominance: Dominance was computed using Simpson's index, where: D = Simpson's index; n = number of Individuals; nt = total number of individuals

$$D = 1 - \sum \frac{n(n-1)}{nt(nt-1)}$$

Species Evenness: Species evenness was computed using Shannon's equitability index (E) to determine the evenness of species. Equitability assumes a value between zero and one, with one for complete evenness, where, E = evenness index, H= Shannon-Wiener Diversity Index, s= number of species, and n= total number of individuals.

$$E = H/Ln(\frac{s-1}{Ln(n)})$$

Species Richness: Species richness is the number of species (S) present in a sample of individuals or found in an area. This was computed using the Menhinick's Index (Magurran 1984) where, R_2 = taxa richness index, S= total number of species observed, N= total number of individuals observed.

$$R_2 = \frac{S}{\sqrt{N}}$$

Distribution Mapping

Species distribution maps were drawn according to ArcGis 10.2 application software. The records of species individuals in particular sampling sites were organized into a point format and each record of the individual species is treated as a separate point indicating its geographical position on a graph expressed as x and y coordinates. Individual species between its minimum and maximum elevations were mapped. In the latter method, the location of individual species was incorporated in a generated digital elevation model and land use map to indicate the distribution of amphibian species. Density maps were drawn using the Heat Map tool in Quantum GIS 2.18 version.

RESULTS AND DISCUSSION

Species Account and Habitat Types

The species of the order Anura comprising of only frogs and toads, were observed in the survey area. A total of 17 anuran species belonging to 7 families was recorded in the survey areas during the survey period (Table 1). These include species under families Ceratobatrachidae (3), Dicroglossidae (4), Megophryidae (1), Microhylidae (1), Ranidae (3), Rhacophoridae (5) and Bufonidae (1). All but one specimen was identified to the species level. The remaining specimen, a Rhacophoridae, was identified to the genus level and full identification is pending secondary analysis. Five major habitat types were identified: agricultural areas, grassland, dipterocarp dominated forest, riparian areas, and lowland forest. Most of the species observed preferred riparian habitat and lowland rainforest.

Table 1. Amphibians observed in Rajah Sikatuna Protected Landscape, Bohol in 2019. X indicates presence and - indicates absence of species found in five habitats.

Family with Species	Elevation range	Habitat Type				
		Agricultural areas	Grassland-Pine habitat	Dipterocarp forest	Riparian habitat	Lowland rainforest
Bufonidae						
Rhinella marina (Linnaeus, 1758)	300 - 450	x	x	-	x	-
Ceratobatrachidae						
Platymantis corrugatus (Taylor, 1922)	325 - 591	-	-	x	x	x
Platymantis guentheri (Dumeril, 1853)	325 - 589	-	x	x	x	x
Platymantis dorsalis (Dumeril, 1853)	385 - 504	-	-	-	-	x
Dicroglossidae						
Fejevarya moodie (Taylor, 1920)	305 - 564	x	x	-	x	x
Limnonectes leytensis (Boettger, 1893)	350 - 469	x	x	-	x	x
Limnonectes visayanus (Inger, 1954)	383 - 500	x	x	-		x
Occidozyga laevis (Gunther, 1858)	300 - 591	x	x	-	x	x
Megophryidae						
Megophrys stejnegeri (Taylor, 1920)	318 - 589	-	-	-	x	x
Microhylidae						
Kalophrynus pleurostigma (Tschudi, 1838)	325 - 587	-	-	x	x	x
Ranidae						
Pulchrana grandocula (Taylor, 1920)	320 - 498	-	-	-	x	x
Sanguirana everetti (Boulenger, 1882)	425 - 550	-	-	-	x	x
Staurois natator (Günther, 1858)	400 - 580	-	-	-	x	x
Rhacophoridae						
Kurixalus appendiculatus (Günther, 1858)	482 - 593	-	-	-	x	x
Philautus sp.	333 - 504	-	x	x	-	x
Polypedates leucomystax (Gravenhorst, 1829)	325 - 564	-	-	-	x	x
***Rhacophorus pardalis* (Günther, 1858)	380 - 490	-	-	-	x	x
Rhacophorus bimaculatus (Peters, 1867)	460 - 575	-	-	-	x	x
Total		5	7	4	15	17

*** Cover page species: *Rhacophorus pardalis* (Günther, 1858).

Spatial Distribution of Species

Bufonidae: *Rhinella marina* (Linnaeus 1758)

Ceratobatrachidae

Platymantis corrugatus (Dumeril, 1853) was observed in all survey areas (Fig. 2I). This Philippine endemic species was found to inhabit forest floor stratum in both undisturbed and disturbed lower montane and lowland forests, and was occasionally found in anthropogenic habitats. *Platymantis dorsalis* was observed in barangays Cabacnitan and Villasuerte. Similar to *Platymantis corrugatus*,

Platymantis guentheri (Boulenger, 1882) was found at all sampling sites inhabiting arboreal microhabitat in lower montane and lowland forests as well as disturbed habitats adjacent to forested areas (Fig. 2K).

Dicroglossidae

Fejevarya moodiei (Taylor, 1920) was found in aquatic microhabitats with elevations ranging from 305-564 masl in all sampling sites except barangay Villasuerte (Fig. 2A). *Limnonectes leytensis* (Boettger, 1893) was found to inhabit streams and rivers in elevation ranging from 350-469m as well as forest edge in barangays Omjon and Valencia (Fig. 2D). *Limnonectes visayanus* (Inger, 1954) thrived in forest edges, agricultural areas, and artificial habitats near natural forests in barangay Villasuerte with an elevation ranging from 383-500m (Fig. 2E). Despite being widespread throughout the Philippines, *Occidozyga laevis* (Günther, 1858) was only found in the bodies of water in barangay Nan-od (Fig. 2G).

Megophryidae

Megophrys stejnegeri (Taylor, 1920) was found among leaf-litter or exposed on the forest floor near tree roots and standing water pools in barangays Bugsoc, Nan-od, Cambuyo and Omjon (Fig. 2F).

Microhylidae

Kalophrynus pleurostigma (Tschudi, 1838**)** was found in the leaf-litter of lowland and hill forests and occasionally in disturbed forests with an elevation ranging from 325-587m in barangays Bugsoc, Nan-od, Cambuyo and Omjon (Fig. 2B).

Ranidae

All three Ranidae species were found in barangay Bugsoc. *Pulchrana grandocula* (Taylor, 1920), also found in barangays Cambuyo and Omjon, inhabited undisturbed and disturbed streams and rivers in montane and lowland forests (Fig. 2M). *Sanguirana everetti* (Boulenger, 1882) (Fig. 2P) inhabited similar habitat as *Pulchrana grandocula* in streams and rivers in lower montane and lowland forests with elevation ranging from 425-550 masl. *Staurois natator* (Günther, 1858) was found along clear, small rocky streams and large rivers with boundaries in primary and secondary forest in hilly terrain (Fig. 2Q).

Rhacophoridae

Kurixalus appendiculatus (Günther, 1858), an arboreal species, was found in elevations ranging from 482-593 masl in swampy areas and small quiet mountains streams in barangays Omjon and Nan-od (Fig 2C). *Philautus* sp., a genus endemic to the Philippines, was found in the forested areas within barangays Bugsoc, Cabacnitan and Villasuerte (Fig. 2H). *Polypedates leucomystax* (Gravenhorst, 1829), found in all sampling sites, inhabited lowland forest and riparian areas (Fig. 2L). *Rhacophorus bimaculatus* (Peters, 1867) was found in riparian areas and lowland rainforests within barangay Cambuyo (Fig. 2N). *Rhacophorus pardalis* (Günther, 1858), also found in riparian and lowland rainforest areas in barangays Cabacnitan, Cambuyo, Omjon and Villasuerte with elevation ranging from 380-490m (Fig. 2O).

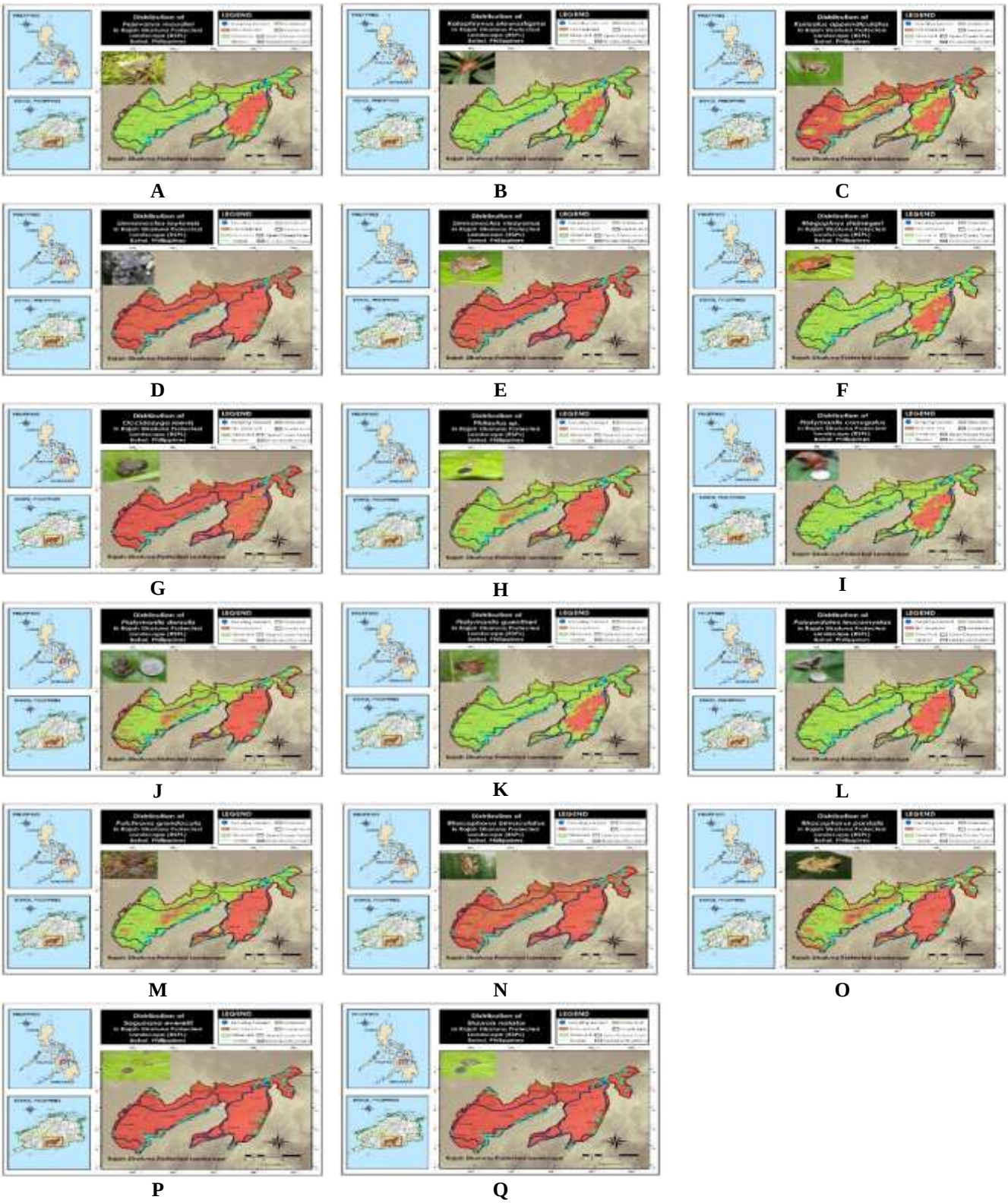

Fig. 2. Suitable habitat spatial distribution of amphibians recorded from Rajah Sikatuna Protected Landscape, Bohol in 2019. Spatial distribution considers the elevation, presence of river and habitat preference

Diversity Pattern

Areas with streams (riparian areas) and open and close canopy forests garnered high concentrations of species and individuals (Fig. 3). *Limnonectes*, *Platymantis*, *Rhacophorus*, *Kalophrynus*, *Kurixalus*, *Pulchrana*, *Sanguirana* and *Staurois* showed a positive association in the forest habitat while *Kaloula*, *Fejervarja*, *Occidozyga* and *Polypedates* showed a positive association in agricultural habitat.

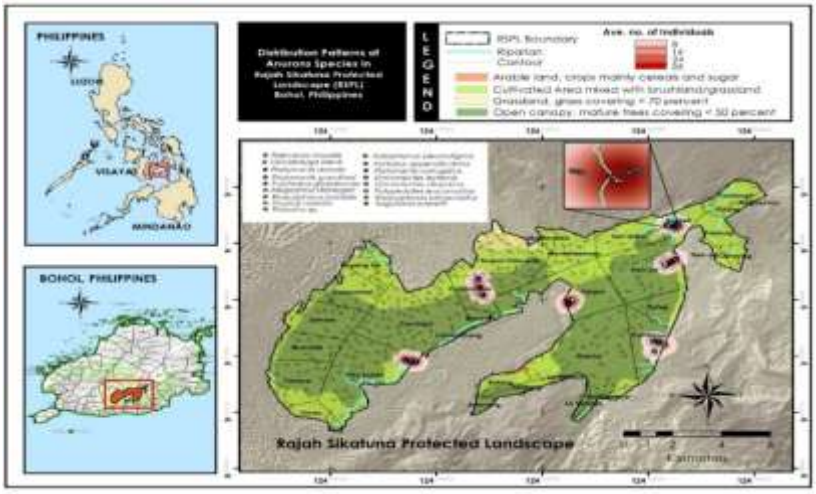

Fig. 3. Vegetation map of Rajah Sikatuna Protected Landscape showing areas with high concentration of amphibians (in red).

Barangay Bugsoc had the highest diversity and dominance index values with H=2.09 and D=0.87, respectively (Fig. 4). This was likely due to the presences of streams inside the forest, the preferred habitat for most of the amphibians observed in the area. Barangays Cabacnitan and Nan-od also had high diversity with H values of 1.8178 and 1.828, respectively. Compared to Barangay Bugsoc, where the streams are bigger, both barangays Cabacnitan and Nan-od were observed to have high degree of anthropogenic disturbance, even within the protected area. Species richness was highest in barangay Omjon. Compared to the other barangays, Omjon had higher elevation and mixed habitat.

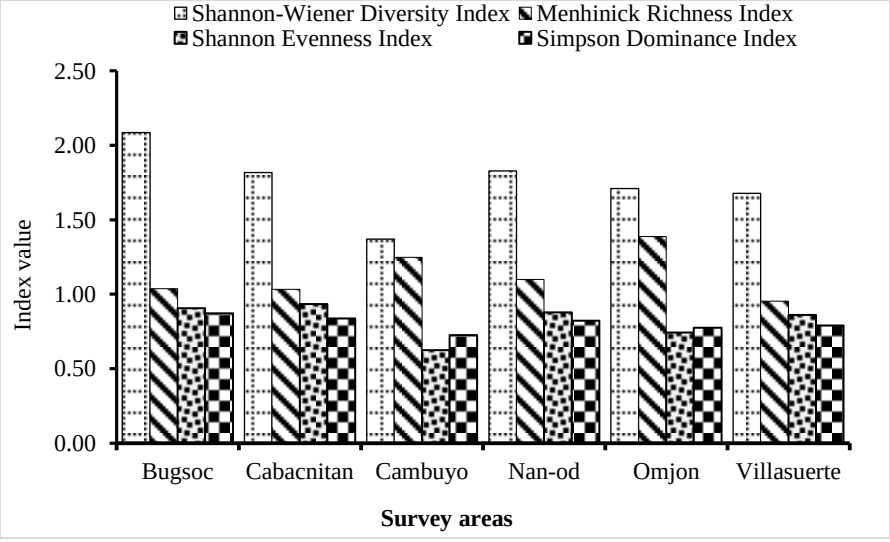

Fig. 4. Diversity index values for the amphibians collected in the Barangays of Rajah Sikatuna Protected Landscape, Bohol.

Consistent with other studies across the Philippines, species known to be more environmentally sensitive were found in higher elevations (450-600 masl) (Gonzales and Dans 1997, Delima *et. al*. 2007, and Gojo Cruz *et. al*. 2019). Elevation affects temperature and humidity and thus affecting egg development and thermal physiology (Navas 2002, Delima *et. al* 2007, Aureo and Bande 2019) especially for more sensitive species.

The positive association between two species (e.g. Forest: *Philautus sp*. and *O. laevis*; Agriculture: *M. stejnegeri* and *K. pleurostigma*) in different habitats may be due to water requirement, environment variables, or acoustic interaction of species (Andres 2009). The collective mapping of species distribution supports the theory of "edge effect" in which two habitats type results in the mixing herpetofaunal elements from the adjacent habitat types (Gonzales and Dans 1997 as cited by Gojo Cruz *et al*. 2019).

Amphibian species in the survey areas are being influenced by varying factors, such as availability of food, habitat preference and microclimatic conditions. The distribution patterns of amphibian species showed high concentration of individuals and species towards mixed vegetation and riparian areas located in mid elevations compared to agricultural, grassland and pine forest found in lower elevations. The variety of species observed showed varying requirements and preferences and could prove that species-specific conservation is important. A distribution map is an effective tool to detect areas for the conservation of amphibian species.

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