Thailand Natural History Museum Journal 17(1): 1–21 (2023)

Land snail diversity of Mount Banahaw-San Cristobal Protected Landscape (MBSCPL) on Luzon Island, Philippines

Kinsley Meg G. Perez[1], Julius A. Parcon[2], Virginia C. Cuevas[1,3] and Emmanuel Ryan C. de Chavez[2,4]

[1]*School of Environmental Science and Management, University of the Philippines Los Baños, College, Laguna 4031, Philippines*.
[2]*Museum of Natural History, University of the Philippines Los Baños, College, Laguna 4031, Philippines*
[3]*Environmental Biology Division, Institute of Biological Sciences, University of the Philippines Los Baños, College, Laguna 4031, Philippines*
[4]*Animal Biology Division, Institute of Biological Sciences, University of the Philippines Los Baños, College, Laguna 4031, Philippines*

Article History
Received: 25 July 2022
Accepted: 16 February 2023
Published Online: 30 June 2023
Printed: 30 June 2023

Corresponding author
Kinsley Meg G. Perez
E-mail: kgperez2@up.edu.ph

Editors
Dr. Weeyawat Jaitrong
E-mail: polyrhachis@yahoo.com/
weeyawat@nsm.or.th
Mr. Michael Cota
Email: Herpetologe@gmail.com
Michael@nsm.or.th

ABSTRACT

Malacofaunal research focused on forest ecosystems is very limited in the Philippines. To address this information gap, the diversity and distribution of land snails were determined in Mount Banahaw, Luzon Island, Philippines. Four slopes (northeast- Lucban, southeast-Tayabas, northwest-Majayjay, and southwest-Dolores) were selected for sampling. A total of 36 plots of 20 x 20 m^2 were set randomly in the protected area. A total of 868 land snails comprising 33 species under 24 genera representing 9 families were sampled. Camaenidae was the most represented family with 10 species. *Ryssota otaheitana* constituted 29.15% of the total number of samples (253 individuals) and was the most abundant species on all the slopes. Of the four slopes, Majayjay has the greatest number of individuals (320) while Lucban has the least (149). In terms of species richness, Dolores has the highest number of species (23) while Tayabas has the least (13). The most abundant species was *Ryssota otaheitana* (253), while *Chloraea hennigiana* (1), *Cyclotus* sp. (1) and *Helicarion* c.f. *cumingii* (1) were the least. Three introduced species from Family Achatinidae were recorded,

Citation. Perez, K.M.G., J.A. Parcon, V.C. Cuevas and E.R.C. de Chavez. 2023.Land Snail Diversity of Mount Banahaw-San Cristobal Protected Landscape (MBSCPL) on Luzon Island, Phillipines. *Thailand Natural History Museum Journal* 17(1): 1–21.

namely, *Lissachatina fulica*, *Allopeas clavulinum*, and *Allopeas gracile*. All invasive species were collected in Dolores. Species accumulation curves (SAC) showed β-dominated pattern of land snails with a completeness ratio of 0.83. The study presented the rich and diverse malacofauna of Mt. Banahaw. It is very important to recognize this protected area as a priority site for malacofaunal conservation.

Keywords: diversity, distribution, macro land snails, micro land snails, Mt. Banahaw, species richness, abundance.

INTRODUCTION

The Philippines is known for its rich biodiversity and is considered one of the 17 regions with high endemism (Mittermeier *et al*., 1999; Posa *et al*., 2008; de Chavez and de Lara, 2011). It has 22,000 described species of mollusks with an estimate of 2% to 4% endemism for marine species (Vallejo, 2002) while, the land snail fauna in the country is immense with approximately 2,000 species and subspecies described (Faustino, 1930; Auffenberg and Páll -Gergely, 2020; Molluscabase, 2022).

The habitat of land snails such as tropical rainforests has experienced threats due to anthropogenic-induced activities. Over 90 years, the Philippines was once almost completely covered by forest. However, it declined from 57.3% to less than 20.5% making the Philippines one of the 25 world hotspots together with Madagascar and Sundaland (Sajise, 2012). Tropical forest ecosystems provide various ecosystem services. This includes resource availability such as fresh water supply and nutrients. Climate regulation, water recycling, cleaning of atmospheric pollutants, and redistributing nutrients are also included (Brandon, 2014). Moreover, tropical forest ecosystems serve as habitats for diverse flora and fauna. Biodiversity enhances ecosystem functioning and services such as pollination and biological pest control (Brandon, 2014).

The continuous decline of forest cover affects the biodiversity of organisms including land snails. Despite this threat, only a single species of land snail, *Helicostyla smargadina* (Reeve,1842), was listed as critically endangered in the International Union for the Conservation of Nature (IUCN) (IUCN, 2006; de Chavez and de Lara, 2011). Other species of edible native snail, *Ryssota otaheitana* (Ferussac, 1821), experienced threats and can be considered vulnerable since it is locally consumed, and thus prone to poaching and illegal trade (Gonzalez *et al*., 2018). Biodiversity studies are very essential in knowing the ecological and habitat requirements of these land snails that are prone to extinction. Knowing this will help in making science-based management and conservation plans.

One of the ideal sites to conduct this type of study was Mt. Banahaw. Mounts Banahaw and San Cristobal were declared as Mt. Banahaw-San Cristobal Protected Landscape (MBSCPL) protected area under the Proclamation No. 411 in R.A. 9847 in 2009 (Gascon, 2002; DENR-BMB, 2015). MBSCPL is considered a unique area for faunal and floral diversity. Endemic species include *Rhynchomys banahao*, *Platymantis banahao*, *Musseromys gulantang*, and *Rafflesia philippensis* (Brown *et al*., 1997; Balete *et al*., 2007; Heaney *et al*., 2013; Pelser *et al*., 2013). However, at present, there are no published journals on the malacofaunal survey done in Mt. Banahaw, thus providing no account of the possible land snail diversity in the protected area. This study aims to determine and analyze the diversity pattern of land snails in Mt. Banahaw. This study will provide baseline information on malacofauna of Mt. Banahaw.

MATERIALS AND METHODS

Study site

Mount Banahaw (13°551’ and 14°10’ latitude, 121°26’ 121°35’ longitude) is the highest mountain (2,158 masl) and largest protected area (109,005,900 m^2) in the Southwestern Luzon Island, Philippines (Fig. 1). It was declared as a protected area under Proclamation No. 411 in R.A. 9847 in 2009 (Gascon, 2002; DENR-BMB, 2015). Different slopes of Mt. Banahaw experience two types of climate (Basconcillo *et al*., 2016). Tayabas and Lucban slopes have Type II climate wherein there is no dry season and wet season occurs from December to February (Basconcillo *et al*., 2016). In contrast, the Majayjay and Dolores slopes have a Type III climate wherein there is a distinct wet and dry season (Basconcillo *et al*., 2016). The dry season occurs from December to February, the wet season occurs the rest of the year (PIDS, 2005; Corporal-Lodangco and Leslie, 2017). The soil type found throughout the volcano is the Luisiana sandy clay loam rich in organic matter which is suitable for growing seasonal crops. Soil pH ranges from 4.4 to 7.2 which is highly acidic to slightly basic (Banaticla and Buot, 2005; Gascon *et al*., 2013; Heaney *et al*., 2013).

The northeastern slope (Lucban) has an elevation of 1,875 masl with a Type II climate. It is managed and protected by the Forest and Conservation Unit of Southern Luzon State University (SLSU). The area was not open to the public and researchers should obtain a permit from the Protected Area and Management Board (PAMB) of Mt. Banahaw-San Cristobal Protected Landscape (MBSCPL) and the university. The entry point was at a satellite campus of SLSU at Barangay (Brgy.) Ayuti, Lucban, Quezon. The area is a combination of agroforests and secondary forests. During the 1970s to 1980s, slash and burn was very rampant in the mountain, starting from 800 masl downwards but during the 1990s it was stopped by the former Mayor Clemente Placino. Nowadays, slash and burn was prohibited in the area. The southeastern slope (Tayabas) has an elevation of 2,140 masl and a Type II climate. It is protected by TAPAT-Kalikasan (Tayabas People’s Action Team for Nature). The entry point is at Brgy. Lalo, Tayabas, Quezon. This area of Mt. Banahaw is regularly visited by mountaineers and nature lovers. However, similar to the northeastern slope, a permit should be first secured from the MBSCPL-PAMB. When going to Camp 1 (Bunkhouse), rice fields, agroforests planted with crops and fruiting trees can be seen. Similar to the Lucban slope at 800 masl downwards of the sampling site was a former slash and burn area way back 1970s to the 1980s. Also, during the 1980s, at 1000-1100 masl elevation, there was a treasure hunting area because people believed that there were hidden treasures left by the Japanese since Camp 2, the last camp before reaching the peak, was a former garrison and old weapons were found there. During the typhoon Glenda (International name Rammasun) in 2014, trees have fallen and changed the trail.

Land Snail Sampling

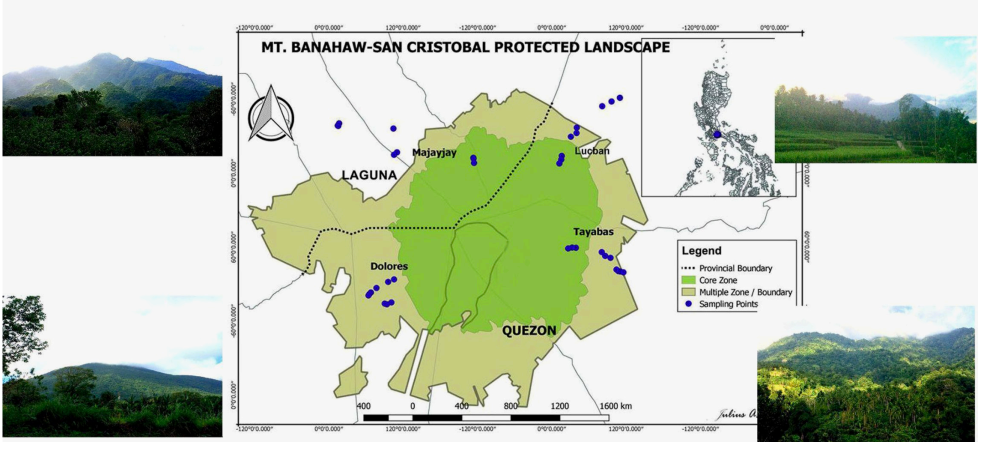

Figure 1. Sampling sites in Mt. Banahaw, Luzon Island, Philippines.

Samples were collected from October to November 2017 using the protocol adapted from Clements *et al*. (2006), Liew *et al*. (2008), de Chavez and de Lara (2011), and Uy *et al*. (2018). Four slopes (northeast- Lucban, southeast-Tayabas, northwest-Majayjay, and southwest-Dolores) were selected for sampling. Within each slope, nine 20 x 20 m (400 m^2) quadrats were set randomly and at least 20 m apart to prevent pseudoreplication. Overall, a total of 36 quadrats (14,000 m^2/ 1.4 ha) was established for the whole study. For each quadrat, three persons extensively searched for live snails (both macro and micro) on stems, underneath leaves, trunks, barks, rotting logs, and on the soil for two hours. A combination of visual searching and sorting of a standard volume of litter and soil were done and as recommended for land snail inventories if repeated visits are not possible (Nurinsiyah *et al*., 2016). Both live and empty shells were collected. Empty shells were considered also since these increases sample size and therefore produce complete malacofaunal inventory especially during one-time sampling (de Winter and Gittenberger, 1998; Cameron and Pokryszko, 2004; Nurinsiyah *et al*., 2016). At each plot, 1L of soil with leaf litter was collected and placed in polyethylene bags while live micro snails were put in 1.5 mL centrifuge tubes with absolute ethanol to preserve their DNA. In the laboratory, the soil was placed in separate basins and was sundried for 2 weeks to remove all moisture content. Afterwards, it was dried in the oven with a temperature of 50° C for 6 hours. The soil was sieved using 3 mm, 2 mm and 1 mm steel meshes to obtain empty shells of micro land snails (<5 mm) (Schilthuizen *et al*., 2002; Clements *et al*., 2008; Liew *et al*., 2008). Both live snails and empty shells were identified up to the species level using published literature (Faustino, 1930; Bartsch, 1932; Springsteen and Leobrera, 1986; Parkinson *et al*., 1987; Abbott, 1989; Bouchet *et al*., 2017). Identified specimens were deposited as vouchers in the University of the Philippines Los Baños Museum of Natural History (UPLB-MNH) while specimens not identifiable to described species were assigned a morphospecies name.

Data analyses

Species richness, abundance, and rarity

In each quadrat, species richness and abundance were determined. The total number of species present in the sampling site was considered as species richness while individual counts for a species were considered as abundance (Colwell, 2009). Relative abundance was computed as:

$$Relative\ abundance = \frac{Species\ abundance}{Total\ abundance}\ x\ 100$$

Species with less than 0.5% of the total individual counts are considered rare (Emberton *et al*., 1997).

Diversity indices:

Diversity was estimated using Shannon index (*H*') (Shannon-Weaver, 1949). Shannon-Weaver Index of diversity (*H*') was determined using the formula:

$$H' = -\sum_{i=1}^{s}(p_i \times lnp_i)$$

where *s* is the total number of species in the community

pi is the proportion of the total sample for the *i*th species (p_i= n/N; n is the important value index of *i*th species and N is the important value index of all the species)

Evenness (*J'*) was determined using the formula:

$$J' = \frac{1}{\sum_{i=1}^{s} P_i{}^2}$$

where *s* is the total number of species in the community

p_i is the proportion of the total sample for the *i*th species

Evenness which is defined as the distribution of individuals in species was the estimated value of the inverse of Simpson's index (Heip *et al*., 1998). The diversity indices were computed using Paleontological Statistics (PAST) software 3.15 (Hammer *et al*., 2001).

Sampling Efficiency

To determine the efficiency of sampling and completeness in all sites, sample-based and individual-based species accumulation curves (SAC) were generated for each slope and the entire Mt. Banahaw using Estimate S version 9.1.0 (Colwell, 2013). Individual-based SAC was based on abundance data and determines the cumulative increase in richness against the number of individual species sampled. Sample-based SAC was based on sampling unit effort and accumulation of new species against the quantum increases of sampling effort represented by quadrats or sampling plots (Dove and Cribb, 2006). SAC was evaluated by calculating the completeness ratio (estimated number of species (S_{ICE}) divided by the observed number of species (S_{OBS}) (Clements *et al*., 2008). The estimated species richness was the incidence-based coverage estimator (S_{ICE}) that was obtained from the extrapolated scores whereas the observed number of species (S_{OBS}) was from the Mau Tao (Uy *et al*., 2018). The shape of a SAC is influenced by the pattern of species richness and relative abundance among the species sampled (Colwell and Coddington, 1994; Thompson and Withers, 2003). It also indicates the type of diversity pattern exhibited by the land snails across the sites (Uy *et al*., 2018).

RESULTS

Land Snail Diversity in Mt. Banahaw

A total of 868 specimens comprising 33 species and 24 genera representing 9 families were sampled in the four slopes of Mt. Banahaw (Table 1; Fig. 2-34).

Camaenidae was the most represented family with 10 species recorded from all slopes, followed by Ariophantidae with 7 species, then by Chronidae and Cyclophoridae with 4 species. Family Achatinidae has 3 species, Trochomorphidae has 2 species while the rest of the families such as Diplommatinidae, Helicinidae, and Pupinidae were represented by a single species. In terms of abundance per family in all the slopes, Chronidae was the most abundant (342) accounting for 39% of the land snails sampled followed by Camaenidae (287), and Cyclophoridae (125).

Among the species, *R. otaheitana* has the highest individual count (253) and constituted 29.15 % relative abundance with a mean density of 0.63 per m^2 from the entire species sampled. It was present in all the slopes and was most abundant in Majayjay (77) while fewest in Dolores (39). *Cochlostyla submirabilis* was the second most abundant species (105) which constituted 12.10% with a mean density of 0.26 per m^2 (Table 1). The third most abundant species was *Cyclophorus woodianus* (103) with 11.87% relative abundance and a mean density of 0.26 per m^2.

Among the species sampled, 30 species are native in the country while 3 species are introduced. These introduced species are from Family Achatinidae (*L. fulica*, *A. clavulinum*, and A. *gracile*). Furthermore, thirteen (13) species were considered rare with a relative den-

Table 1. Land snail diversity, abundance and density in Mt. Banahaw, Philippines. D- Dolores T-Tayabas L-Lucban M-Majayjay; *- native species **-introduced species

Family	Genus/ Species	D	T	L	M	TOTAL	Relative abundance (%)	Relative density (400 m²)	Remarks
Achatinidae	*Allopeas clavulinum* (Potiez & Michaud,1838) **	7	0	1	0	8	0.92	0.02	
	Allopeas gracile (T. Hutton, 1834) **	2	0	1	0	3	0.35	0.01	Rare
	Lissachatina fulica (Bowdich, 1822)**	6	0	0	0	6	0.69	0.02	
Ariophantidae	*Helicarion* c.f. *cumingii*	0	0	0	1	1	0.12	0.00	Rare
	Helicarion sp.	2	2	1	4	9	1.04	0.02	
	Microcystina mp1	11	0	0	1	10	1.38	0.03	
	Microcystina mp2	0	1	1	0	2	0.23	0.01	Rare
	Pseudhelicarion sp.	0	0	2	0	2	0.23	0.01	Rare
	Semperoncis montanus (Plate, 1893)	0	0	2	0	2	0.23	0.01	Rare
	Vitrinula biangulata (L. Pfeiffer, 1844)	0	0	0	4	4	0.46	0.01	Rare
Camaenidae	*Calocochlea* mp1	4	0	0	0	4	0.46	0.01	Rare
	Calocochlea mp2	2	0	3	2	7	0.81	0.02	
	Chloraea hennigiana (Möllendorff, 1893)	1	0	0	0	1	0.12	0.00	Rare
	Cochlostyla submirabilis (Möllendorff, 1897)	2	41	18	44	105	12.10	0.26	
	Helicostyla bicolorata (I. Lea, 1840)	4	1	18	21	44	5.07	0.11	
	Helicostyla mirabilis (Férussac, 1821)	15	13	6	18	52	5.99	0.13	
	Helicostyla rufogaster banahaoana (Bartsch, 1932)	1	3	7	20	31	3.57	0.08	
	Helicostyla woodiana (I. Lea, 1840)	0	2	4	0	6	0.69	0.02	
	Hypselostyla dactylus (Broderip, 1841)	0	11	3	14	28	3.23	0.07	
	Obba listeri (Gray, 1825)	6	0	0	3	9	1.04	0.02	
Chronidae	*Hemiglypta cuvieriana* (I. Lea, 1840)	6	6	8	34	54	6.22	0.14	
	Hemitrichiella setigera (G. B. Sowerby I, 1841)	0	2	6	7	15	1.73	0.04	
	Kaliella sp.	14	5	0	1	20	2.30	0.05	
	Ryssota otaheitana (Férussac, 1821)	39	72	65	77	253	29.15	0.63	
Cyclophoridae	*Cyclophorus reevei* (Hidalgo, 1888)	1	0	0	1	2	0.23	0.01	Rare
	Cyclophorus woodianus (I. Lea, 1840)	85	0	0	18	103	11.87	0.26	
	Cyclotus sp.	1	0	0	0	1	0.12	0.00	Rare
	Leptopoma helicoides (Grateloup, 1840)	9	0	1	9	19	2.19	0.05	
Diplommatinidae	*Diplommatina microstoma* (Möllendorff, 1887)	3	0	0	0	3	0.35	0.01	Rare
Helicinidae	*Sulfurina citrina* (Grateloup, 1840)	14	0	0	33	47	5.41	0.12	
Pupinidae	*Moulinsia aurantia* (Grateloup, 1840)	0	0	0	4	4	0.46	0.01	Rare
Trochomorphidae	*Videna metcalfii* (L. Pfeiffer, 1845)	4	1	2	2	9	1.04	0.02	
	Videna repanda (Möllendorff, 1890)	0	0	0	2	2	0.23	0.01	Rare
Total number of individuals		**239**	**160**	**149**	**320**	**868**			
Number of species		**23**	**13**	**18**	**22**	**33**			

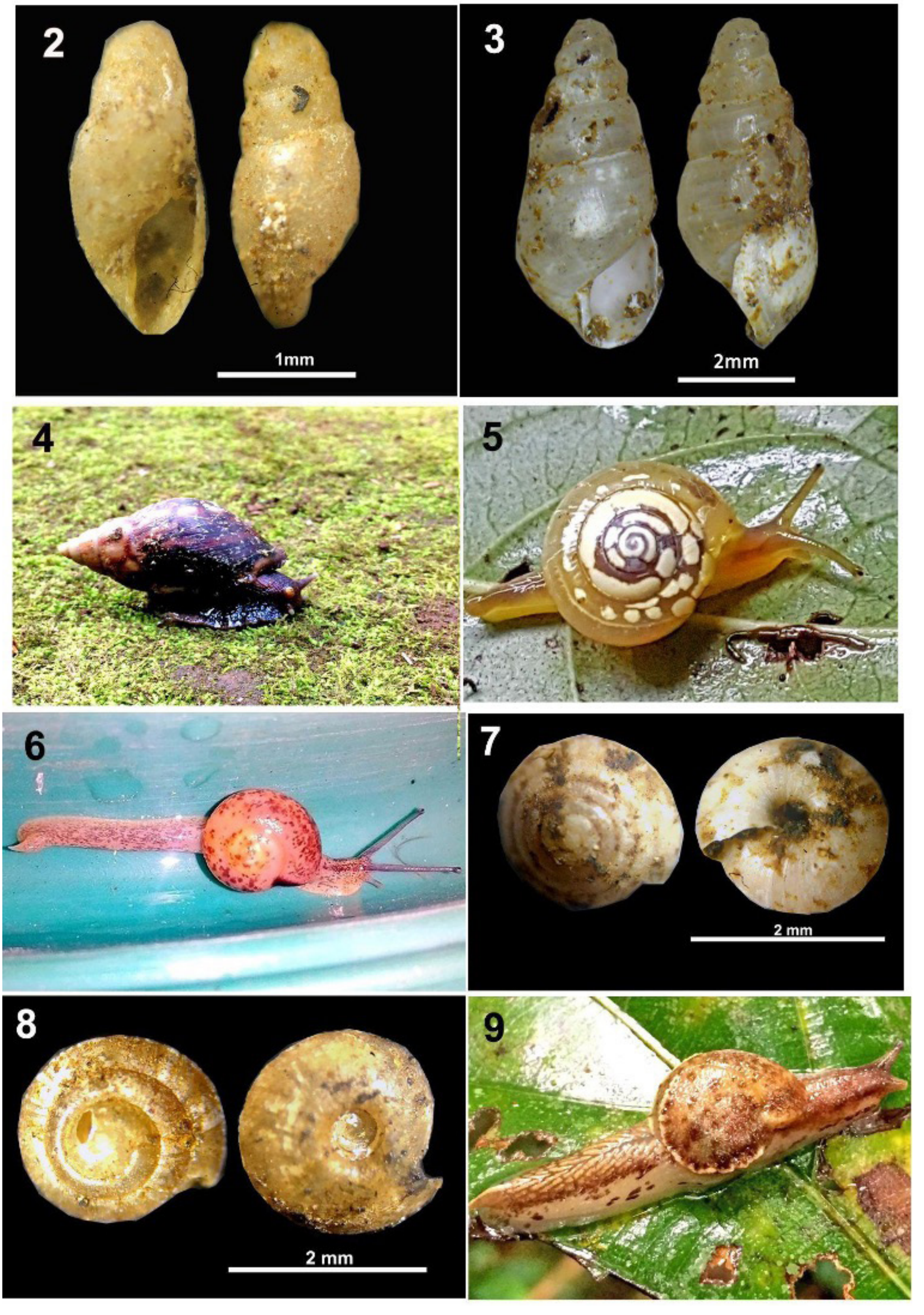

Figure 2-9. Live land snails found in Mt. Banahaw: 2) *Allopeas clavulinum* (Potiez & Michaud, 1838); 3) *Allopeas gracile* (T. Hutton, 1834); 4) *Lissachatina fulica* (Bowdich, 1822); 5) *Helicarion* c.f. *cumingii*; 6)*Helicarion* sp.; 7) *Microcystina* mp1; 8) *Microcystina* mp2; 9) *Pseudhelicarion* sp.

Figure 10-15. Live land snails found in Mt. Banahaw: 10) *Semperoncis montanus* (Plate, 1893); 11) *Vitrinula biangulata* (L. Pfeiffer, 1844); 12) *Calocochlea* mp1; 13) *Calocochlea* mp2; 14) *Chloraea hennigiana* (Möllendorff, 1893); 15) *Cochlostyla submirabilis* (Möllendorff, 1897).

sity of less than 0.5% (Table 1).

Diversity Indices

Table 2 shows the diversity indices. Among the slopes, Majayjay has the highest individual counts (320) while the least was Lucban (149). In terms of species richness, Dolores has the highest number of species (23 species) while Tayabas was the least with 13 species

Figure 16-23. Live land snails found in Mt. Banahaw: 16) *Helicostyla mirabilis* (Ferussac, 1821); 17) *Helicostyla woodiana* (I. Lea, 1840); 18) *Helicostyla bicolorata* (I. Lea, 1840); 19) *Hypselostyla dactylus* (Broderip, 1841); 20) *Helicostyla rufogaster banahaoana* (Bartsch, 1932); 21) *Obba listeri* (Gray, 1825); 22) *Hemiglypta cuvieriana* (I. Lea, 1840); 23) *Hemitrichiella setigera* (G. B. Sowerby I, 1841).

only (Table 2). Among the four slopes, Majayjay was the most diverse and even (H'=2.46; J'=0.53). It also obtained the highest Simpson index score of 0.88. To summarize the malacofaunal diversity in Mt. Banahaw, a total of 868 specimens were obtained from 33 species. A diversity index of 2.55 and a dominance score of 0.13 were obtained. This means that if a Simpson score or dominance (D') is near to zero, it indicates a relatively high species diver-

Figure 24-30. Live land snails found in Mt. Banahaw: 24) *Kaliella* sp.); 25) *Ryssota otaheitana* (Ferussac, 1821); 26) *Cyclophorus woodianus* (I. Lea, 1840); 27) *Cyclophorus reevei* (Hidalgo, 1888); 28) *Leptopoma helicoides* (Grateloup, 1840); 29) *Cyclotus* sp.; 30) *Diplommatina microstoma* (Möllendorff, 1887)

sity. Based on the Simpson index of diversity, there is about 87% probability of obtaining two randomly chosen individuals belonging to the two different species in the community. This suggests high species richness. An evenness score of 0.39 which is closer to zero indicates few species dominating in the study site (Table 2).

SAC

The generated SACs (Fig. 35) differentiate the estimated species richness to the number of quadrats and individuals in each of the slopes and the entire sampling site, Mt. Banahaw. The graph showed a β-dominated pattern of land snails characterized by late asymptote. Moreover, it showed a high completeness ratio (CR=0.83) for all the sampling areas in Mt. Banahaw.

Figure 31-34. Live land snails found in Mt. Banahaw: 31) *Moulinsia aurantia* (Grateloup, 1840); 32) *Sulfurina citrina* (Grateloup, 1840); 33) *Videna metcalfii* (L. Pfeiffer, 1845); 34) *Videna repanda* (Möllendorff, 1890).

Table 2. Diversity indices of slopes in Mt. Banahaw, Luzon Island, Philippines.

Slopes	**Diversity index**					
	Species Richness	**Abundance**	**Shannon_(*H'*)**	**Evenness_(*J'*)**	**Dominance_(*D'*)**	**Simpson (1-D)**
Dolores	23	239	2.33	0.45	0.17	0.83
Tayabas	13	160	1.66	0.41	0.28	0.72
Lucban	18	149	2.03	0.42	0.23	0.77
Majayjay	22	320	2.46	0.53	0.12	0.88
Mt.Banahaw	33	868	2.55	0.39	0.13	0.87

DISCUSSION

The study showed the diversity and distribution of land snails in Mt. Banahaw. Land snail assemblage in Mt. Banahaw has a relatively higher diversity (868 specimens comprising 33 species representing 9 families) compared to Mt. Makiling with 639 identified individuals belonging to 14 species from five families (de Chavez and de Lara, 2011). Mt. Banahaw also has relatively diverse land snails compared to Marinduque with 29 identified species from 16 families (Sosa *et al*., 2014). On the other hand, Mt. Banahaw has relatively lower diversity than in Masungi Georeserve which has 43 species from 12 families (Valdez *et al*., 2021).

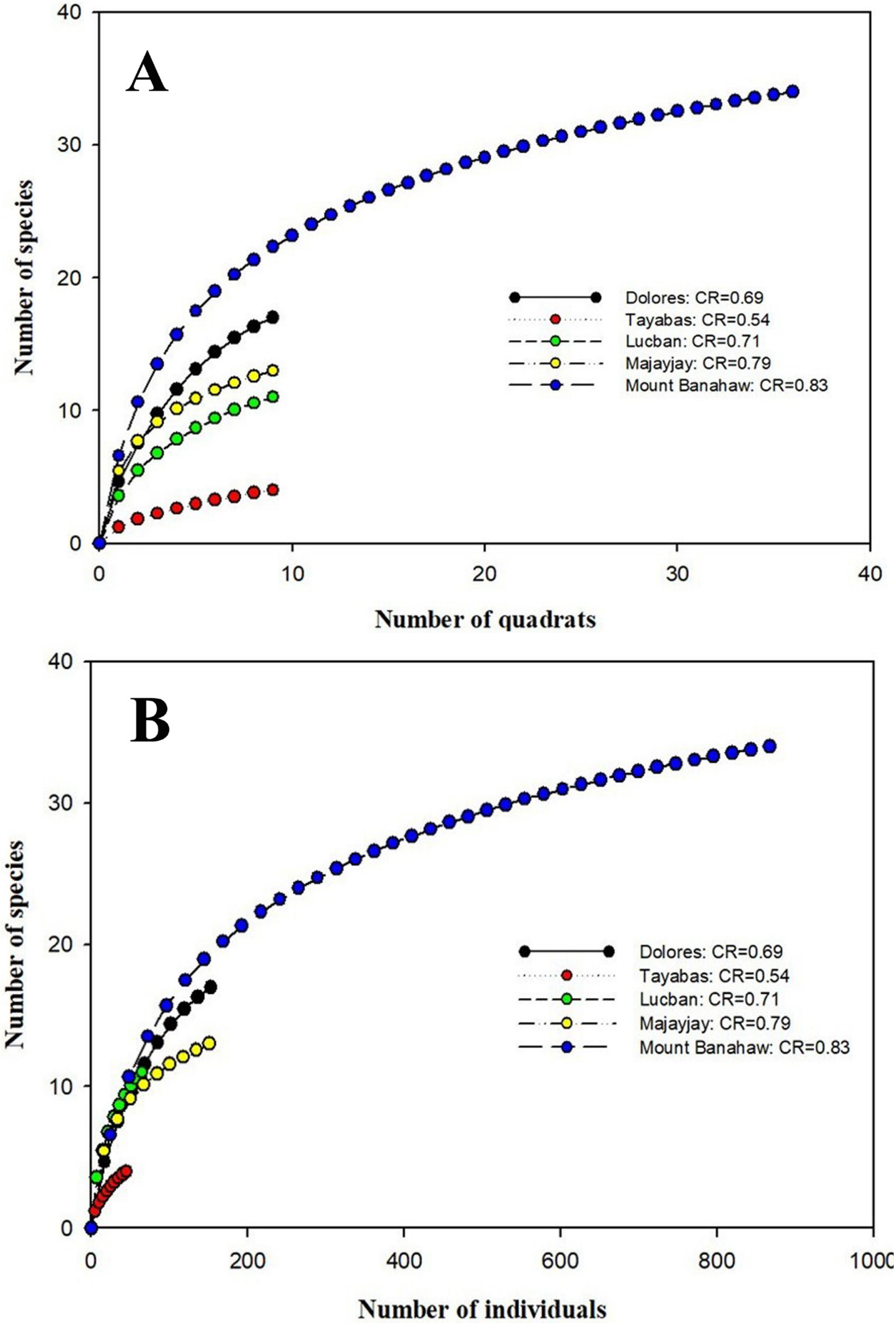

Figure 35. Sample-based (A) and individual-based (B) species accumulation curves of land snails in the slopes of Mt. Banahaw, Luzon Island, Philippines.

However, Mt. Banahaw and Masungi Georeserve are not comparable because of the different methodologies used as well as the difference in the environment whereby the former is a non-karst rainforest ecosystem while the latter was sampled in both karst and non-karst areas. Moreover, the malacofaunal diversity in non-karst rainforest ecosystems is lower than in karst areas (Liew *et al*., 2008). This can be attributed to calcium leaching that was caused by active forest litters that increase the acidity of the soil (Schilthuizen and Rutjes, 2001; Schilthuizen *et al*., 2003). Uy *et al*. (2018) revealed that low pH promotes calcium leaching and hastens the bioerosion of shells.

On the other hand, the abundance and distribution of land snails are correlated with their microhabitat requirements such as stable, temperate, litter-rich, and moderately moist forests (Solem, 1984; Schilthuizen and Rutjes, 2001). The abundance and diversity of endemic macro land snails were highest in intact and undisturbed forests. Moreover, endemic species such as helicostylids have a strong association with native forests making them potential indicators of a healthy forest ecosystem (de Chavez and de Lara, 2011). The presence of large trees in old-growth forests and secondary forests provide shading to land snails to prevent desiccation. Old-growth forests contain high organic layer accumulation that provides moisture to micro snails to prevent them from desiccation (Martin, 2000; Kappes *et al*., 2006).

Furthermore, the introduced species also has a factor in the diversity and distribution of native species of land snails in Mt. Banahaw. Introduced species such as the giant African snail, *L. fulica*, were documented in the sampling site. It was also reported by de Chavez and de Lara (2011) in Mt. Makiling, Marinduque (Sosa *et al*., 2014), Mt. Lantoy in Cebu (Rosales *et al*., 2020), Masungi Georeserve (Valdez *et al*., 2021), and Sta. Teresita, Cagayan (Parcon *et al*., 2021). It serves as a disturbance indicator since it is present in anthropogenic-induced environments or highly disturbed forests, plantations, and former slash-and-burn sites (Parcon *et al*., 2021). This pattern is also observed in East Java, Indonesia (Nurinsiyah *et al*., 2016; Nurhayati *et al*., 2021). The abundance of introduced pulmonate species increased with decreasing canopy cover and increasing human impact (Nurinsiyah *et al*., 2016). In the study of Nurhayati *et al.* (2021), *Bradybaena similaris*, an invasive species, is more abundant in Sumber Brantas Arboretum than in Raden Soerjo Forest Park Conservation Area (Tahura). The Arboretum has lesser canopy cover and more anthropogenic-induced activity than in Tahura.

Other introduced species such as *A. clavulinum*, and *A. gracile* were also documented in MBSCPL. Among the four slopes, all introduced species were observed in Dolores while the two species of *Allopeas* were present in Lucban slope. Uy *et al*. (2018) also reported the presence of *A. clavulinum*, and *A. gracile* on their study at Mt. Makiling.

Based on diversity index, MBSCPL has a relatively high index of diversity (*H*'= 2.55). but lower when compared to Masungi Georeserve's diversity index with *H*' = 2.94 (Valdez *et al*., 2021). According to Magurran (2004), the diversity index in the natural ecosystem ranges from 1.5–3.5, wherein the value above 3.0 indicates a stable habitat while under 1.0 indicates a highly disturbed environment. In addition, Flores and Zafaralla (2012) stated a diversity index of less than 2.5 is relatively low. Thus, MBSCPL has a relatively high diversity index.

Based on the SACs, land snail community assemblage showed a β -dominated pattern in MBSCPL that is characterized by late asymptotes. A β -dominated pattern means that fewer quadrats and individuals were needed in order to capture the entire species diversity. This indicates that many species can be found in a relatively small area and that these species are interactive. This also suggests that the sampling sites were saturated, niche assembled, and locally rich. Although the completeness ratio in MBSCPL is relatively high (0.83), the sampling is not enough as the asymptote graph is still going upward. This means that more species can be sampled in the study site. To capture the total diversity, more quadrats (~ 40) and individuals (~ 950) were needed in order to attain a completeness ratio of 1. Furthermore, sampling for two periods with increased sampling effort can potentially increase the total diversity of land snails for this study. Nonetheless, the sample-based and individual-based SACs in the study site showed a relatively high completeness ratio.

Aside from the ecological requirements of land snails, the abundance of predators, poaching for food and shell trades, and habitat destruction will eventually lead to the extinction of these economically important species (Solem, 1984; Schilthuizen and Rutjes, 2001; de Chavez and de Lara, 2011). Land snails serve as a food source for small mammals, amphibians, reptiles, birds, arthropods, and humans (Sen *et al*., 2012; Rosales *et al*., 2020). In Mt. Banahaw, certain species are locally consumed such as *R. otaheitana* an edible native species, locally known as *bayuko* in Laguna and *bikuyo* in Quezon provinces. The same species was also consumed in Mt. Makiling (de Chavez and de Lara, 2011). Despite the local consumption, it was still the most abundant snail in Mt. Banahaw. Gonzalez *et al*. (2018) proposed the status of this helical snail, *R. otaheitana*, to be vulnerable (VU) species that were threatened with global extinction. Justifications included were this snail was known only from extremely limited range and habitat, known from limited distribution, prone to poaching and illegal trade, and known from localities under severe threat or with high human disturbance. In Cebu Island, an arboreal endemic land snail *Helicostyla daphnis* locally known as *takyong* was also consumed by locals. It was exploited for food and shell trades in a municipality in North Cebu (Funesto and Flores, 2017). Others claimed that it has relieved respiratory and allergy-related ailments like asthma. It was also seemed to be a good source of stamina and energy, others considered it as an aphrodisiac (Funesto and Flores, 2017). Similar to *R. otaheitana*, the *H. daphnis* was also proposed status to be vulnerable in Philippine faunal conservation (Gonzalez *et al*., 2018).

Tropical forest ecosystems serve as habitats for land snails. Many native species of Philippine land snails were abundant in forest ecosystems than in plantations (de Chavez and de Lara, 2011). Moreover, endemic land snails are more diverse in intact and undisturbed forests (de Chavez and de Lara, 2011). Deforestation has been attributed to slash and burn farming, mining, and forest conversion into non-forest uses such as road construction, human settlement, and conversion into built-up areas. Also, natural calamities, logging (both legal and illegal), charcoal making, and timber poaching are also included (Carandang *et al*., 2013). The continued exploitation of natural resources causes the decline in the country's biodiversity which includes land snails. Land snails are prone to natural and anthropogenic disturbance due to their extremely limited mobility and dispersal. They serve as good ecological indicators of rainforest biodiversity (Baur and Baur, 1998; Uy *et al*., 2018). Thus, this study suggests the inclusion of land snails in science-based management plans for the protected area for their protection and conservation to prevent population decline and extinction. Strict guidelines should also be implemented to prevent unregulated harvesting, poaching, and shell trades of endemic species.

CONCLUSION

This study suggests high malacofaunal diversity in Mt. Banahaw. Native land snails are good indicators of undisturbed habitats. Moreover, it is highly recommended to include land snails in management plans for their protection and conservation to prevent population decline and extinction. Strict guidelines should also be implemented to prevent unregulated harvesting, poaching, and shell trades of endemic species. Eradication of invasive species should also be included.

ACKNOWLEDGEMENTS

The authors would like to thank UPLB Basic Research and the Department of Science and Technology- Accelerated Science and Technology Human Resource Development Program (DOST-ASTHRDP) for the fund support. Also, the authors would like to acknowledge the Mt Banahaw-San Cristobal Protected Landscape- Protected Area Management Board MBSCPL-PAMB and the Department of Environment and Natural Resources (DENR) IV-A for the permit (R4A-WGP-2018-QUE-022). The authors would like to thank the local government units (LGUs) of Dolores, Tayabas, Lucban, and Majayjay. The authors would like to acknowledge Dr. Gizelle A. Batomalaque for the species identification and verification and Mr. Sedney S. Mendoza for the layout of the photos.

REFERENCES

Abbott, T. 1989. *Compendium of Landshells: A Color Guide to More Than 2,000 of the World's Terrestrial Shells*. Melbourne, FL: American Malacologists. 411 pp.

Auffenberg, K and B. Páll-Gergely. 2020. Reassignment of Three Species and One Subspecies of Philippine Land Snails to the Genus Acmella Blanford, 1869 (Gastropoda:

Assimineidae). *Tropical Natural History* 20(3): 223–227.

Balete, D.S., E.A. Rickart, R.G.B. Rosell-Ambal, S.A. Jansa and L.R. Heaney. 2007. Descriptions of two new species of *Rhynchomys* Tomas (Rodentia: Muridae: Murinae), from Luzon Island, Philippines. *Journal of Mammalogy* 88: 287–30.1

Banaticla, M.C.N. and I. Buot Jr. 2005. Altitudinal Zonation of pteridophytes on Mt. Banahaw de Lucban, Luzon Island,Philippines. *Plant Ecology* 180: 135–151.

Bartsch, P. 1932. The Philippine land mollusks *Cochlostyla rufogaster* and *Obba marmorat*a and their races (Contributions to the biology of the Philippine Archipelago and adjacent regions). *Smithsonian Institution, United States National Museum Bulletin* 100(6): 329–342.

Basconcillo, J., A. Lucero, A. Solis, R. Sandoval, Jr., E. Bautista, T. Koizumi and H. Kanamaru. 2016. Statistically Downscaled Projected Changes in Seasonal Mean Temperature and Rainfall in Cagayan Valley, Philippines. *Journal of the Meteorological Society of Japan*. Ser. II. 94A. 151–164. 10.2151/jmsj.2015-058.

Baur, A. and B. Baur. 1998. Altitudinal variation in size and composition of eggs in the land snail *Arianta arbustorum. Canadian Journal of Zoology*.76: 2067–2074.

Bouchet, P., J.P. Rocroi, B. Hausdorf, A, Kaim, Y. Kano, A. Nützel,P. Parkhaev, M. Schroedl and E. Strong. 2017. Revised Classification, Nomenclator and Typification of Gastropod and Monoplacophoran Families. *Malacologia*. 61. 1–526. 10.4002/040.061.0201.

Brandon, K. 2014. Ecosystem Services from Tropical Forests: Review of Current Science. *SSRN Electronic Journal*. 10.2139/ssrn.2622749.

Brown, R.,A.C. Diesmos and A.C. Alcala, 1997. Species of the *guentheri* group of *Platymantis* with descriptions of four new species. *Proceedings of the California Academy of Sciences*, sér. 4. 50(1):.1–20.

Cameron, R.A.D. and B.M. Pokryszko. 2004. Land mollusk faunas of Bialowieza forest (Poland), and 917 the character and survival of forest faunas in the North European Plain. *Journal of Molluscan Studies* 70: 149–164.

Carandang, A.P., L.A. Bugayong, P.C. Dolom, L.N. Garcia, M.B. Villanueva, N.O. Espiritu and the Forestry Development Center. 2013. *Analysis of Key Drivers of Deforestation and Forest Degradation in the Philippines.*Manila, Philippines: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Clements, G.R., N. Sodhi, P. Ng and M. Schilthuizen. 2006. Limestone Karsts of Southeast Asia: Imperiled Arks of Biodiversity. *BioScience* 56: 733–742.

Clements, G.R., X.X. Lu, S. Ambu, M. Schilthuizen and C.J.A. Bradshaw. 2008. Using biogeographical patterns of endemic land snails to improve conservation planning for limestone karsts. *Biological Conservation* 141(11): 2751–2764.

Colwell, R.K. 2009. In S.A. Levin, S.R. Carpenter, H.C.J. Godfrey, A.P. Kinzig, M. Loreau, J.B. Losos, B. Walker and D.S. Wilcove (eds.) Chapter III.1: *Biodiversity: Concepts,* *Patterns, and Measurements. Princeton Guide to Ecology.*Princeton Press. pp. 257–263.

Colwell, R.K. 2013. Estimates: Statistical estimation of species richness and shared species from samples. *Version 9.1.0. User's Guide and application.* Downloaded from http://purl.oclc.org/estimates on 20 January 2018.

Colwell, R.K. and J. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of B Biological Sciences* 345(1311):101–118.

Corporal-Lodangco, I. and L. Leslie. 2017. Defining Philippine Climate Zones Using Surface and High-Resolution Satellite Data. *Procedia Computer Science* 114. 324–332. 10.1016/j.procs.2017.09.068.

de Chavez, E.R.C. and A.V. de Lara. 2011. Diversity and spatial distribution patterns of macro land snails in Mount Makiling Forest Reserve, Philippines. *Asia Life Sciences* 20: 183–197.

de Winter, A.J., and E. Gittenberger. 1998. The land snail fauna of a square kilometer patch of rainforest in southwestern Cameroon: high species richness, low abundance and seasonal fluctuations. *Malacologia* 40: 231–250.

Department of Environment and Natural Resources Biodiversity Management Bureau (DENR-BMB). 2015. *Guidebook to Protected Areas of the Philippines*. Philippines: Biodiversity Management Bureau – Department of Environment and Natural Resources. pp. 30–35.

Dove, A.D.M. and T.H. Cribb. 2006. Species accumulation curves and their application in parasite ecology. *Trends in Parasitology* 22: 568–574.

Emberton, K.C., T.A. Pearce, P.F. Kasigwa, P. Tattersfield and Z. Habibu. 1997. High diversity and regional endemism in land snails of eastern Tanzania. *Biodiversity and Conservation* 6: 1123–1136.

Faustino, L. 1930. Summary of Philippine land shells. *Philippine Journal of Science* 48:85–198.

Flores, M.J. and M.T. Zafaralla. 2012. Macroinvertebrate Composition, Diversity and Richness in Relation to the Water Quality Status of Mananga River, Cebu, Philippines. *Philippine Science Letters* 5(2): 103–113.

Funesto, E.G. and M.J. Flores. 2017. Effects of physicochemical factors and the local ecological knowledge on the population of *Helicostyla daphnis* (Broderip, 1841) in Borbon and Sogod, Cebu, Philippines. *Applied Ecology and Environmental Research* 15:1455–1471.

Gascon, C.N. 2002. *Mt. Banahaw*. Physical, Biological and Management Feature Foundation for the Philippine Environment, SYNERGOS, ASEAN Regional Centre for Biodiversity Conservation, and Southern Luzon Polytechnic College.

Gascon, C.N., R.C. Garcia, F.N. Beltran, W.C. Faller and M.A.R. Agudilla. 2013. Biodiversity Assessment of Mt. Banahaw de Dolores, Philippines. *Asian Journal of Biodiversity* 295(4): 23–45.

Gonzalez, J.C., D.G. Tabaranza, C. Layusa, C.P. Española, L.E. Afuang, W.A.C. van de Ven, L.R. Heaney, M.L.L. Diesmos and D.S. Balete. 2018. Review and update of the 2004 National List of Threatened Terrestrial Fauna of the Philippines. Sylvatrop, *The Technical Journal of Philippine Ecosystems and Natural Resources* 28(1): 73–144.

Hammer, Ø., D.A.T. Harper and P.D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologica Electronica* 4(1) p. 9.

Heaney, L.R., D.S. Balete, R. Grace, R.G.B. Rosell-Ambal, M.J.S. Veluz, S. Veluz and E. Rickart. 2013. The small mammals of Mt. Banahaw-San Cristobal National Park, Luzon, Philippines: Elevational Distribution and Ecology of a Highly Endemic auna. *National Museum of the Philippines. Journal of Natural History*. pp. 45–60.

Heip, C.H.R., P.M.J. Herman and K. Soetaert. 1998. Indices of diversity and evenness. *Oceanis* 24(4):61–87.

International Union for Conservation of Nature (IUCN). 2006. Storch I (compiled by). 2007. *Grouse Status Survey and Conservation Action Plan 2006-2010*. IUCN & World Pheasant Association, Gland, Switzerland & Fordingbridge, UK. Downloaded from http://www.biodiversitya-z.org/content/habitat-degradation on 26 October 2017.

Kappes, H., W. Topp, P. Zach and J. Kulfan. 2006. Coarse woody debris, soil properties and snails (Mollusca: Gastropoda) in European primeval forests of different environmental conditions. *European Journal of Soil Biology* 42. 10.1016/j.ejsobi.2005.12.003.

Liew, T.S., G.R. Clements and M. Schilthuizen. 2008. Sampling micromolluscs in tropical forests: one size does not fit all. *Zoosymposia* 1: 271–280.

Magurran, A.E. 2004. *Measuring Ecological Diversity*. Oxford, UK: Blackwell Publishing. p. 256

Martin, S.M. 2000. Terrestrial snails and slugs (Mollusca: Gastropoda) of Maine. *Northeastern Naturalist* 7(1):33–88.

Mittermeier, R.A., N. Myers, C.G. Mittermeier and G.P. Robles.1999. *Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions*. CEMEX, SA, Agrupacion Sierra Madre, S.C.

MolluscaBase eds. 2022. *MolluscaBase*. Accessed at https://www.molluscabase.org on 2022-07-21. doi:10.14284/448

Nurhayati, P.A., M. Affandi and A.S.Nurinsiyah. 2021. Diversity and abundance of terrestrial Gastropods on the slopes of Mount Arjuna-Welirang, East Java, Indonesia. *Biodiversitas Journal of Biological Diversity* 22: 4193-4202. 10.13057/biodiv/d221009.

Nurinsiyah, A.S., H. Fauzia, C. Hennig and B. Hausdorf. 2016. Native and introduced land snail species as ecological indicators indifferent land use types in Java. *Ecological Indicators* 70. 10.1016/j.ecolind.2016.05.013.

Parcon, J.A., I.L. Lit Jr., M.V.D.C. Camacho and E.R.C. de Chavez.2021. Diversity of Land Snails in the Karst Areas of Sta. Teresita, Cagayan Province, Luzon Island with Notes on New Distribution Records. *Philippine Journal of Science* 150(S1): 525–537

Parkinson, B., J.Hemmen and K. Groh. 1987. *Tropical Landshells of the World*. Germany: Verlag Christa Hemmen.

Pelser, P., D. Nickrent, J.R. Callad and J. Barcelona. 2013. Mt. Banahaw reveals: The resurrection and neotypification of the name *Rafflesia lagascae* (Rafflesiaceae) and clues to the dispersal of Rafflesia seeds. *Phytotaxa* 131: 35-40. 10.11646/phytotaxa.131.1.6.

Philippine Institute for Development Studies (PIDS). 2005. Basics on Philippine Climatology. *Economic Issue of the Day* 5(2) Downloaded from https://dirp4.pids.gov.ph/ris/eid/pidseid0502.pdf on 16 August 2020.

Posa, M.R.C., A.C. Diesmos, N.S. Sodhi and T.M. Brooks. 2008. Hope for threatened tropical biodiversity: lessons from the Philippines. *BioScience* 58(3): 231–240.

Rosales, R., E. Lillo, S. Alcazar, L. Colita, J. Caballero and A. Baltazar. 2020. Species composition, relative abundance, and distribution of land snail species in Mt. Lantoy Key Biodiversity Area, Cebu, Philippines. *Biodiversitas Journal of Biological Diversity* 21. 10.13057/biodiv/d211152.

Sajise, P.E. 2012. *Ecology, Environment, and Sustainable Development: Reflections Spanning Five Decades*. UPLB: Southeast Asian Regional Center for Graduate Study and Research in Agriculture.

Schilthuizen, M. and H.A. Rutjes. 2001. Land snail diversity in a square kilometer of tropical rain forest in Sabah, Malaysian Borneo. *Journal of Molluscan Studies* 67:417–423

Schilthuizen,M., M.I.F. Teravainen, N. Faezamoltha,K. Tawith, H. Ibrahim, S.M. Chea, C.P. Chuan, L.J. Daim, A. Jubaidi, M.J. Madjapuni, M. Sabeki and A. Mokhtar. 2002. Micro snails at Microscales in Borneo: Distribution of Prosobranchia versus *Pulmonata.Journal of Molluscan Studies* 68:255–258.

Schilthuizen, M., H.N. Chai, T.E. Kimsin and J.J. Vermeulen. 2003. Abundance and diversity of land-snails (Mollusca: Gastropoda) on limestone hills in Borneo. *The Raffles Bulletin of Zoology* 51: 35–42.

Sen, S., Ravikanth, G. and N.A. Aravind. 2012. Land snails (Mollusca: Gastropoda) of India: status, threats, and conservation strategies. Journal of Threatened Taxa 4(11): 3029–3037.

Shannon, C.E. and W. Weaver. 1949. *The Mathematical Theory of Communication.* Urbana, Illinois, USA: University of Illinois Press. 117 pp..

Solem A. 1984. A world model of land snail diversity and abundance. In Solem, A. and A.C. Bruggen (Eds.) *World-wide snails: Biogeographical studies on Non-marine Mollusca*. Brill: Leiden. pp. 6–22.

Sosa, B.O. III, G.A. Batomalaque and I.K.C. Fontanilla. 2014. An Updated Survey and

Biodiversity Assessment of the Terrestrial Snail (Mollusca: Gastropoda) Species in Marinduque, Philippines. *Philippine Journal of Science* 143(2): 199–210.

Springsteen, F.J. and F.M. Leobrera. 1986. *Shells of the Philippines*. Manila, Philippines: Carfel Seashell Museum. pp. 339–354, 377.

Thompson, G. and P. Withers. 2003. Effect of species richness and relative abundance on the shape of the species accumulation curve. *Austral Ecology* 28 (4).

Uy, B.B., N. Cadiz and E.R.C. de Chavez. 2018. Ecological patterns of micro land snails along the altitudinal gradients of Mount Makiling, Philippines. *Journal of the International Society for Southeast Asian Agricultural Sciences* 24. 30–42.

Valdez, B.K, J.A. Parcon and E.R.C. de Chavez. 2021. Malacofaunal diversity and distribution in the Masungi Georeserve in Luzon Island, Philippines. *Philippine Science Letters* 14(1).

Vallejo, B. 2002. Molluscs, p. 50. In: Ong, P.S., L.E. Afuang and R.G. Ambal (Eds.). *Philippine Biodiversity Conservation Priorities: A Second Iteration of the National Biodiversity Strategy and Action Plan*. Philippines: Department of Environment and Natural Resources-Protected Areas and Wildlife Bureau, Conservation