Distribution of endemic and threatened herpetofauna in Mt. Malindang, Mindanao, Philippines

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ORIGINAL PAPER

Distribution of endemic and threatened herpetofauna in Mt. Malindang, Mindanao, Philippines

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Abstract Mt. Malindang is one of the upland ranges where biodiversity has been severely threatened due to forest loss. Fieldwork was conducted from October 2003 to December 2004 in 14 sampling sites from an elevation of 120 to over 1,700 m above sea level to assess the distribution of endemic and threatened herpetofaunal species. Twenty-six species of amphibians and 33 species of reptiles were observed for all sampling sites. The level of endemism for amphibians was 42% where 7 of the 11 recorded species are found only in Mindanao. Nine species were in the threatened category, 8 vulnerable and 1 endangered. For the reptiles, 48% endemicity was observed. No threatened species was found. Field observations show that the major threat to the herpetofauna is habitat destruction, particularly the conversion of the forest to agricultural farms by the local people. It was also observed that endemic and threatened species were distributed in high elevation sites (submontane, dipterocarp, almaciga, and montane forests). Despite habitat loss in Mt. Malindang, 18% of the recorded herpetofaunal species recorded in the Philippines were found in Mt. Malindang, indicating the conservation importance of this mountain range.

Keywords Endemic · Herpetofauna · Mindanao · Mt. Malindang · Species · Threatened

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Introduction

The herpetofauna are very good indicators of ecosystem health. A decrease or the absence of frogs, especially forest dwellers and endemic species would indicate a disturbance in their habitat. Range size, habitat loss, and more extreme seasonality in precipitation contributed to decline risk in the 2,454 amphibian species that declined between 1980 and 2004, compared to species that were stable ($n = 1{,}545$) or had increased ($n = 28$). These empirical results show that amphibian species with restricted ranges should be urgently targeted for conservation (Sodhi et al. 2008), and one of the Southeast Asian countries that needs immediate attention is the Philippines. The rapid destruction of tropical rainforest in Southeast Asia in the twentieth century drastically altered the environmental conditions where many forms of vertebrate life had been adapted (Sodhi et al. 2004). The Philippines is regarded by nearly every major international conservation organization as one of the top global priorities for conservation action (Heaney and Oliver 1997). An account of the country's herpetofaunal biodiversity lists down 101 amphibians with 79 endemic species and 258 reptiles with 170 endemics (Diesmos et al. 2002).

Mt. Malindang is one of the upland ranges in the Philippines where biodiversity has been severely threatened due to forest loss. It is the highest mountain (2,175 masl) in the Zamboanga peninsula, a western part of Mindanao. The Malindang range is part of the national park, the boundaries of which define the Important Bird Areas (IBA). While several bird species with a restricted-range and threatened status have been reported from Mt. Malindang, limited information has been reported for herpetofauna. A survey conducted by Tabaranza et al. (2001) in Mt. Malindang reported 26 herpetofaunal species belonging to nine families. This study presents additional information on the species richness as well as the distribution of the endemic and threatened species of herpetofauna in Mt. Malindang.

Methodology

Fourteen sampling sites in Mt. Malindang (Fig. 1) were established for herpetofaunal survey.

Sampling site 1. This site was a mossy forest (1,700 masl) with a plant community of *Ascarina philippinensis* and *Xanthomyrtus diplycosifolium.* The canopy layer was mainly composed of *Viburnum* sp., *Lithocarpus* sp., *Caldeluvia* sp., *Pometia* sp., *Macaranga deptirocarpifolia*, *Polyosma philippinensis*, *Clethra lancifolia*, *Podocarpus neriifolius*, *Syzygium*, and *Polyosma philippinensis*. Other vegetations were: canopy epiphytes {wild orchids, bird's nest fern (*Asplenium* sp.) and mosses}; the canopy vines {*Plagiogyria* sp., *Pteris tripertita*, *Smilax* sp. and climbing pandan (*Freycinetia* sp.)} and the understory plants {*Clethra lancifolia*, tree ferns (*Cyathea*), ferns and the ground cover plants, mosses, and lichens}. Fallen trees were moderately to commonly abundant. The distance to the nearest creek was 50–300 m for subsite 1; more than 300 m for subsite 2. Both subsites were at a distance of 500–2,000 m from the nearest anthropogenic clearing.

Sampling site 2. This montane forest (1,400–1,700 masl) had a plant community of *Clethra lancifolia* and *Impatiens montalbanica. Lithocarpus philippinensis, Lithocarpus mindanaensis, Polyosma philippinensis, Gordonia luzonica,* and *Clethra lancifolia* made up the canopy layer. Epiphytic ferns, wild orchids, lichen, and mosses were observed. Canopy vines included the *Smilax* sp., *Piper* sp., and *Freycinetia* sp. The forest understory was made up of saplings and shrubs. Bryophytes and ferns covered the ground. *Pandanus*

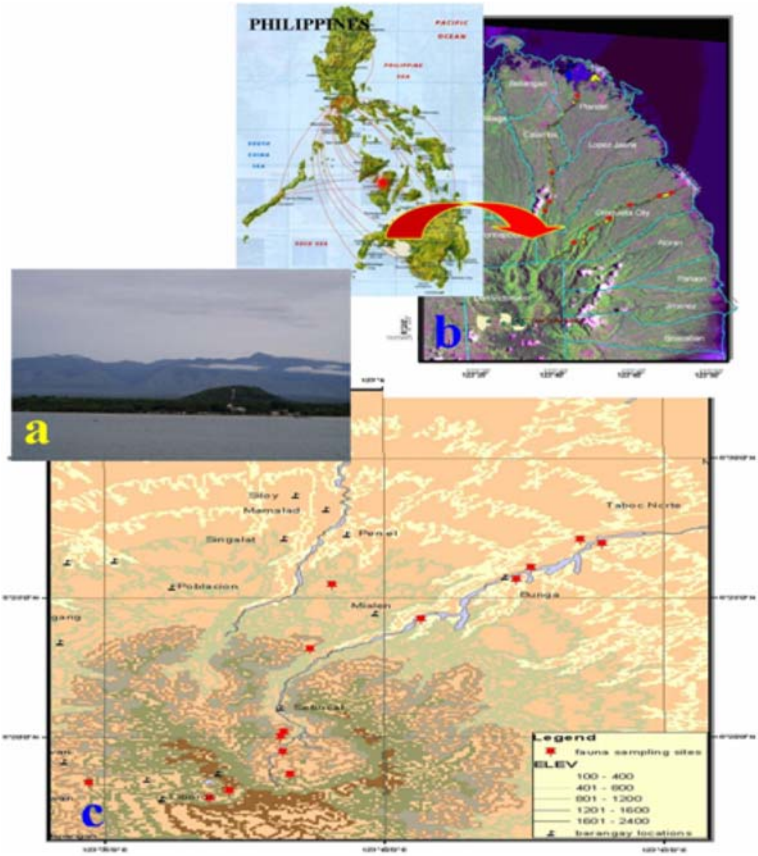

Fig. 1 **a** Panoramic view and **b** location map of Mt. Malindang showing **c** the 14 sampling sites

sp. was moderately abundant. The moss density was moderately high. Fallen trees and exposed rocks were common 50–500 m away from the creek to the site. The site was disturbed by timber extraction.

Sampling site 3. This almaciga forest (1,200–1,400 masl) was dominated by a community of *Agathis philippinensis* which ranged in height from 15 to 40 m, together with *Cinnamomum mercadoi*. Epiphytic plants such as wild orchids, bird's nest fern, and vines were observed. Few pitcher plants, *Musa*, and some fruit-bearing plants were recorded. Tree ferns, saplings, seedlings of almaciga trees, and ferns comprised the understory plants. Fallen trees were observed moderately frequently. The site was 100 m away from a river. Timber extraction was the main disturbance in the area.

Sampling site 4. This site was located at the mid elevation and characterized as the submontane dipterocarp forest (900–1,000 masl). It had a dominant plant community of *Ficus minahassae* and *Bischofia javanica*. *Shorea negrensis* was the emergent tree at 15–30 m in height. The canopy layer was at 10–15 m in height. Epiphytic ferns, wild orchids, mosses, pandan, and bamboo were found. Tree ferns, saplings, shrubs, and palm trees were some of the understory plants recorded. *Ficus* and pandan were moderately frequent. Slightly moist loam soil was covered with 1–2 cm humus and a moderate dense layer of leaf litter. The gathering of rattan was observed. The river was a distance of less than 1,000 m.

Sampling site 5. This site was the lowland dipterocarp forest (220–500 masl) just 5 m away from a creek in Barangay Mialen, with a plant community of *Ficus variegata* and *Selaginella moellendorfi.* Coconut trees dominated the lower elevation (subsite 1) with some fruit-bearing trees such as mango and guava. *Musa* was moderately common. The upper elevation (subsite 2) had *Lithocarpus* sp. with a height ranging from 10 to 15 m and DBH of 1 m; and *Dendrocnide* sp. with 6–8 m height. The ground was covered with sedges. Mosses, lichens, bird's nest fern were epiphytic to the canopy. Small-scale farming, clearings, and trails were the disturbance to the site. The upper elevation was less than 1.5 km away from the Layawan River while the lower elevation was about 200–500 m away.

Sampling site 6. This site was a mixed dipterocarp forest (450–900 masl). It had a plant community of *Syzgium* and *Sticherus laevigata.* The height of emergent tree ranged from 10 to 15 m while the canopy trees ranged from 3 to 5 m in height. Canopy epiphytes and only one species of canopy vine were found; understory plants were rarely observed. Fruit-bearing plants were moderately abundant while fallen trees were rarely observed. The site was 100–200 m away from Langaran River. Anthropogenic disturbances observed were the clearings, farms, and trails.

Sampling site 7. This site was a mixed lowland dipterocarp forest (220–450 masl). The dominant vegetation was composed of Diplodiscus *paniculatus* and *Lithocarpus* sp. Subsite 1 was 200 m away from Layawan River. The area was planted with coconuts and fruit trees. Cogon (*Imperata cylindrica*) and other grasses covered the ground. Subsite 2 was a hilly/mountainous area. The ground was covered with grasses and ferns. Several fruit-bearing trees were abundant. Exposed rocks were moderately abundant. Subsite 2 was about 100 m away from Layawan River.

Sampling site 8. The plantation forest site 1 (120–900 masl) was located in Barangay Peniel about 400 m away from a creek. This site had a plant community of *Acacia mangium, Cocos nucifera*, and other fruit trees.

Sampling site 9. The plantation forest site 2, in Barangay Bunga, had the same vegetation as plantation forest site 1. Subsite 1 was 1.5 km away from a water course while subsite 2 was 75–100 m away from the Layawan River.

Sampling site 10. This was Agroecosystem site 1 (1,400–1,550 masl) at Barangay Lake Duminagat. This site was located adjacent the montane forest. Fruiting plants like wild raspberries, *Medinilla*, and *Senna septemtrionalis* were commonly observed. Bare rocks were moderately abundant. Small-scale vegetable farms were observed throughout the cultivated area; cogon grass (*Imperata cylindrica*) made up most of the principal ground cover of grassland. The nearest creek was at 50–100 m.

Sampling site 11. Agroecosystem site 2 in Barangay Sebucal (1,235–1,550 masl) was adjacent to the almaciga forest in the same barangay. Ferns, *Imperata cylindrica* and grasses covered the ground. Together with mixed vegetables, corn and sugarcane, fruit-bearing plants like *Homolanthus, Tremma*, and *Everittia* were found. Exposed rocks were moderately common. The site was 50 m away from the Layawan River.

Sampling site 12. Agroecosystem site 3, Barangay Mansawan. This site was adjacent to a forest at a lowland at elevation of 600–985 masl.

Sampling site 13, Agroecosystem site 4 (Barangay Peniel, 600–610 masl) and Sampling site 14, Agroecosystem site 5 (Barangay Mamalad, 165–465 masl) were habitats in the lowland with high degree of disturbance due to farming activities.

Sampling of amphibians and reptiles was done using the cruising method for a total of 203 field days. Aquatic, subterranean, surface, and arboreal strata were searched for amphibians by day (0600 hours–0800 hours) and at night (1800 hours–2200 hours). Sampling for reptiles was done late in the morning to the early afternoon (1000 hours–1400 hours) and in the evening (1800 hours–2200 hours) to capture nocturnal reptiles. Reptiles were searched by digging and trenching using bolos and sticks, climbing arboreal strata of the forest, checking isolated pools, seepage areas, tree holes, burrows, rotten logs, vines, ant mounds, leaf litter, tree foliage, and other microhabitats.

Two to three voucher specimens of each species captured (the permit limit), particularly species not identified in the field, were prepared following standardized preservation techniques (Heyer et al. 1994). These specimens were deposited at the Natural Science Museum of the Mindanao State University-Iligan Institute of Technology, Iligan City. Reference works such as Inger (1954), Brown and Alcala (1978, 1980), Alcala (1986), and Alcala and Brown (1998) were used for species identification. Nomenclature followed Alcala and Brown (1998) for amphibians and Alcala (1986) for reptiles. A list of endemic and threatened species was generated based on published data and IUCN criteria.

Seriation using the Markov Monte Carlo method was used to determine assemblage of herpetofaunal species by placing the species into sequence so that the sampling sites with the most similar proportions of certain taxa are together. This was done using PAST software developed by Hammer et al. (2001).

Results

We recorded a total of 59 herpetofaunal species from the 14 sites explored within the Mount Malindang range (Tables 1, 2). These included 26 amphibians and 33 reptiles. Of these species, 27 are endemic to the Philippines including seven species, all amphibians, that have a range that is restricted to Mindanao (Table 3). The 59 species recorded in this study form 18% of the total number recorded for the Philippines as a whole ($n = 324$) (Table 4).

Two amphibian species *Limnonectes magnus* and *Rana grandocula* were found to be the most widely distributed being found in 11 of the 14 sampling sites. The Mindanao endemic and vulnerable *Philautus acutirostris* was also found to be widely distributed (nine sampling sites) from the higher to lower elevation and in almost all habitat types. The Mindanao endemic *Ansonia mcgregori* was found in eight sites while *Philautus surrufus*, and *Philautus worcesteri* were distributed in seven sampling sites. Interestingly, *Ichthyopis mindanaoensis*, a Mindanao endemic caecilian was found only in two sites. The Philippine endemic *Philautus surdus. was* noticeably found in the four forest sampling sites at higher elevation and in the lowland dipterocarp forest. Other endemic species were found only in one or two sampling sites mostly in the forest sampling sites at higher elevation.

Five of the six endemic species in the mossy forest are Mindanao endemic. These were *Ansonia mcgregori, Philautus acutirostris, Philautus poecilus,* and *Philautus worcesteri* which are of vulnerable status and the endangered *Philautus surrufus*. The Mindanao endemic species found in the mossy forest were also present in the montane and almaciga forests.

Among the reptiles, the Philippine endemic *Sphenomorphus fasciatus* was the most widely distributed. Another endemic species, *Rhabdophis auriculata* was found in five sampling sites while *Naja samarensis* was found in four sampling sites. Other endemic species had limited distribution in one to three sampling sites.

Among the sampling sites surveyed, the submontane dipterocarp forest had the highest species richness for amphibians and reptiles followed by the lowland dipterocarp forest.

Table 1 Species list of amphibians (nomenclature follows Alcala and Brown 1998)

Species	Sampling sites													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
*Ansonia mcgregori*** Taylor	4	23	5	7	0	0	0	0	2	2	5	0	0	1
Bufo marinus Linnaeus	0	0	0	0	2	0	1	0	2	1	2	1	1	0
Chaperina fusca Mocquard	0	0	2	3	0	6	1	0	0	0	0	3	0	0
*Ichthyophis mindanaoensis*** Taylor	0	0	0	4	1	0	0	0	0	0	0	0	0	0
Leptobrachium hasselti Muller	0	0	0	0	0	0	0	0	0	0	1	0	0	0
*Limnonectes leytensis** Boettger	0	0	0	0	1	3	0	0	0	0	0	0	0	0
*Limnonectes magnus** Stejneger	0	0	3	2	1	6	2	1	1	6	4	8	0	2
*Limnonectes parvus*** Taylor	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Megophrys stejnegeri Kuhl and Van Hasselt	0	6	0	1	1	0	1	2	1	0	0	0	0	0
*Nyctixalus spinosus** Taylor	0	0	0	2	0	0	0	0	0	0	0	0	0	0
*Occidozyga laevis*Gunther	0	0	0	0	0	0	0	1	0	0	0	1	1	0
*Philautus acutirostris*** Peters	36	18	27	50	1	0	1	3	0	0	2	1	0	0
*Philautus poecilus*** Brown and Alcala	11	4	0	0	0	0	0	0	0	0	0	0	0	0
Philautus sp. A	22	0	0	0	1	0	0	0	0	0	0	0	0	0
Philautus sp. B	7	0	0	1	0	0	0	0	0	0	0	0	0	0
Philautus sp. C	0	0	0	0	2	0	0	0	0	0	0	0	0	0
*Philautus surdus** Peters	23	8	1	0	1	0	0	0	0	0	0	0	0	0
*Philautus surrufus*** Brown and Alcala	70	14	3	8	6	0	0	0	0	1	2	0	0	0
*Philautus worcesteri*** Stejneger	22	7	1	3	0	0	0	0	0	1	1	1	0	0
Platymantis dorsalis Dumeril	0	1	0	1	0	0	1	0	0	0	0	0	0	0
Platymantis rabori Brown	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Polypedates leucomystax Gravenhorst	0	0	0	2	2	2	1	0	0	0	0	15	1	1
Rana grandocula	0	1	3	8	13	5	0	1	0	4	1	11	1	8
Rhacophorus bimaculatus Peters	0	0	6	10	1	0	0	0	0	0	0	0	0	0
Rhacophorus pardalis Gunther	0	0	0	1	0	0	0	0	0	0	2	1	0	0
Staurois natator Gunther	0	0	0	0	9	2	0	1	1	0	0	0	0	1

Legend: * Philippine endemic ** Mindanao endemic

Nos. indicate no. of individuals

A mossy forest, *B* montane forest, *C* almaciga forest, *D* submontane dipterocarp forest, *E* lowland dipterocarp forest, *F* mixed dipterocarp forest, *G* mixed lowland dipterocarp forest, *H* plantation (peniel 12), *I* plantation (Bunga), *J* agro ecosystem (Barangay lake), *K* agro ecosystem sebucal, *L* agro ecosystem mansawan, *M* agro ecosystem peniel, *N* agro ecosystem mamalad

High species richness for amphibians was also documented in the forest sampling sites at high elevation and in two agroecosystem areas. Reptiles were noticeably absent in the mossy and montane forest sites as well as in one plantation site and one agroecosystem site. Low species richness was noted in the mixed dipterocarp forests and in three agroecosystem sites.

High amphibian endemism was recorded in sampling sites at high elevation like the mossy forest, montane forest, almaciga forest, and agroecosystem sites 1 and 2. Reptilian

Table 2 Species list of reptiles (nomenclature follows Alcala 1986)

Species	Sampling sites													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Ahaetulla prasina Reinwardt	0	0	1	2	3	0	0	2	1	0	0	0	0	0
Aplopeltura boa Boei	0	0	0	1	0	0	0	2	0	0	0	0	0	0
Boiga dendrophila Boei	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Brachymeles boulengeri	0	0	0	0	0	0	0	0	0	0	2	0	0	0
*Calamaria gervaisi** Dumeril and Bibron	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Calamaria lumbricoidea	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Calotes sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0
*Cyclocorus lineatus** Reinwardt	0	0	0	0	1	0	0	1	0	0	0	0	0	0
*Cyrtodactylus annulatus** Taylor	0	0	0	0	2	0	1	0	0	0	0	1	0	0
*Dasia grisea**	0	0	0	0	0	0	0	2	0	0	1	0	0	0
Dendrelaphis caudolineatus Peters	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Draco sp.	0	0	0	0	1	1	0	0	1	0	0	0	0	0
Elaphe erythrura Dumeril and Bibron	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Gekko gecko Linnaeus	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gonocephalus sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hemidactylus frenatus Dumeril and Bibron	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Mabuya multicarinata Gray	0	0	0	0	1	0	0	1	0	0	0	3	0	0
Mabuya multifasciata Gray	0	0	0	0	1	0	2	0	0	0	5	8	0	1
*Naja samarensis** Linnaeus	0	0	1	1	1	0	1	0	0	0	0	0	0	0
Opisthotrophis alcalai	0	0	0	1	0	0	0	0	0	0	0	0	0	0
*Oxyrhabdium modestum** Gunther	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Psammodynastes pulverulentus Boei	0	0	7	12	0	0	0	1	0	0	0	1	0	0
Pseudorabdion sp.	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Python reticulatus	0	0	1	1	1	0	0	0	0	0	0	0	0	0
*Rhabdophis auriculata** Gunther	0	0	0	1	3	0	1	0	0	1	0	1	0	0
*Sphenomorphus abdictus**	0	0	0	0	0	0	1	0	0	0	0	0	0	0
*Sphenomorphus cumingii**	0	0	0	0	0	0	0	1	0	0	0	0	0	0
*Sphenomorphus fasciatus** Gray	0	0	1	3	1	0	1	0	0	0	4	7	0	0
*Sphenomorphus steerei** Stejneger	0	0	3	1	0	0	0	0	0	0	1	0	0	0
*Sphenomorphus variegates*** Peters	0	0	0	1	0	0	0	0	0	0	1	1	0	0
*Trimeresurus flavomaculatus** Gray	0	0	0	0	0	0	0	1	1	0	0	0	0	0
*Tropidonophis dendrophiops**	0	0	0	1	0	0	1	2	0	0	0	0	0	0
*Tropidophorus misaminus** Stejneger	0	0	0	1	2	0	0	0	0	0	0	0	0	1

Legend: * Philippine endemic ** Mindanao endemic

Nos. indicate no. of individuals

A mossy forest, *B* montane forest, *C* almaciga forest, *D* submontane dipterocarp forest, *E* lowland dipterocarp forest, *F* mixed dipterocarp forest, *G* mixed lowland dipterocarp forest, *H* plantation (peniel 12), *I* plantation (Bunga), *J* agro ecosystem (Barangay lake), *K* agro ecosystem sebucal, *L* agro ecosystem mansawan, *M* agro ecosystem peniel, *N* agro ecosystem mamalad

endemism was observed to be high in the submontane dipterocarp forest, lowland dipterocarp forest and in two agroecosystem sites at high elevation which are adjacent to a forest.

Table 3 Species richness and endemism of the herpetofauna in Mt. Malindang

Sampling sites	A	B	C	D	E	F	G	H	I
(1) Mossy forest (over 1,700 masl)	8	6 (5)	75	0	0	0	8	6	75
(2) Montane forest (1,400–700 masl)	9	6(5)	67	0	0	0	9	6	67
(3) Almaciga forest (1,200–1,400 masl)	10	6(4)	60	6	3(0)	50	16	9	56
(4) Submontane dipterocarp forest (900–1,100 masl)	17	8(6)	47	13	9(0)	69	30	17	57
(5) Lowland dipterocarp forest (220–500 masl)	14	6(3)	43	12	8(0)	67	26	14	54
(6) Mixed dipterocarp forest (450–900 masl)	7	2(0)	28	2	0	0	9	2	22
(7) Mixed lowland dipterocarp forest (220–450 masl)	7	2(1)	28	8	5(0)	62	15	7	47
(8) Plantation forest1 (120–900 masl)	8	3	38	8	4	50	16	7	44
(9) Plantation forest 2 (120–900 masl)	6	2	33	3	0	0	9	2	22
(10) Agroecosystem 1 (1,400–1,550 masl)	7	5	71	1	1	100	8	6	75
(11) Agroecosystem 2 (1,235–1,550 masl)	10	6	60	8	5	63	18	11	61
(12) Agroecosystem 3 (600–985 masl)	10	4	40	11	6	55	21	10	48
(13) Agroecosystem 4 (600–610 masl)	4	0	0	1	0	0	5	0	0
(14) Agroecosystem 5 (165–465 masl)	5	2	40	6	1	17	11	3	27
Total # of species	26			33			59		
Endemic species	11			16			27		
Mindanao island endemic	7			0			7		
% Endemism	42			48			46		
% of Mindanao endemics (total species)	27			0			12		
% of Mindanao endemics(phil. endemics)	64			0			26		

Legend: *A* no. of species amphibians, *B* phil. endemic (Mindanao endemic), *C* % endemic amphibians, *D* no. of species reptiles, *E* phil. endemic (Mindanao endemic), *F* % endemic reptiles, *G* total no. of species, *H* phil. endemic (Mindanao endemic), *I* % endemic herpetofauna

Table 4 Herpetofaunal species richness in Mt. Malindang

	Mt. Malindang this study	Mt. Malindang (Don Victoriano) (Tabaranza et al. 2001)	Philippines (Alcala et al. 2006)
Amphibians	26 (11)	16	110 (79)
Reptiles	33 (16)	10	197 land, ca 17 marine (170)
Total number of species	59 (27)	26	324 (249)

Legend: () Philippine endemic

More threatened species were found in the sampling sites at high elevation (Table 5) compared to the low elevation sampling sites. No threatened species was recorded for reptiles.

A high amphibian diversity was recorded in the lowland dipterocarp forest as well as in the agroecosystem site in Sebucal. Other sampling sites exhibited moderate diversity. Over-all amphibian diversity was high. A more or less even distribution was noted for amphibians except in the submontane forest which recorded low evenness. Pooled data,

Table 5 Distribution of threatened species of herpetofauna in Mt. Malindang (conservation status follows IUCN 2007)

Sampling sites	Amphibians	Reptiles
(1) Mossy forest	5 (1Endangered (E) 4Vulnerable (V)	0
(2) Montane forest	6 (1E,5 V)	0
(3) Almaciga forest	5 (1E,4 V)	0
(4) Submontane dipterocarp forest	8 (1E,7 V)	0
(5) Lowland dipterocarp forest	4 (1E,3 V)	0
(6) Mixed dipterocarp forest	0	0
(7) Mixed lowland dipterocarp forest	2 V	0
(8) Plantation forest 1 (120–900 masl)	2 V	0
(9) Plantation forest 2 (120–900 masl)	2 V	0
(10) Agroecosystem 1 (1,400–1,550 masl)	3 (2 V, 1E)	0
(11) Agroecosystem 2 (1,235–1,550 masl)	5 (4 V, 1E)	0
(12) Agroecosystem 3 (600–985 masl)	3 V	0
(13) Agroecosystem 4 (600–610 masl)	0	0
(14) Agroecosystem 5 (165–465 masl)	1 V	0
Threatened species	9	0
Threatened phil. endemic (Mindanao endemic)	7(6)	0
% Threatened species	35	0

Legend: *E* endangered, *V* vulnerable

however, showed high diversity and a more or less even distribution. A much higher diversity was recorded for reptiles but the distribution was less even (Table 6).

A graphical structure of the communities of herpetofauna in the fourteen sampling sites was done using seriation, a method typically applied to an association between taxa and sampling stations (Brower and Kile 1988) (Figs. 2, 3). The seriation reorganized the data matrix such that the presence of the taxa is concentrated along the diagonal. The results showed that the structures of the communities are closely associated with the elevation pattern of the sampling sites.

Rarefaction analysis was done on the abundance data using the algorithm from Krebs (1989) to estimate the number of species if the sample sizes for all sites were equal. The paleontological statistics software developed by Hammer et al. (2001) was used to compute for the estimates. Results showed that the estimated species richness matched with that of the observed (Table 7).

Discussion

Species distribution showed that only the endemic *Ansonia mcgregori* and the *Philautus* group were found in the mossy forest. Changes in the abundance of certain types of breeding sites with altitude may affect amphibians (Inger and Stuebing 1989). In the mossy forest of Mt. Malindang, the terrain was so steep that most breeding habitats formed by rainfall were shallow and swift, and diminished quickly in volume because of rapid run-off. Inger and Stuebing (1989) explained that the lack of various types of breeding microhabitats, specifically lentic microhabitats, at higher elevations might have favored the

Table 6 Diversity indices of the 14 sampling sites

Sampling sites	Amphibians			Reptiles			Herps		
	Species	Shannon	Evenness	Species	Shannon	Evenness	Species	Shannon	Evenness
Mossy forest	8	1.785	0.745	0	0	0	8	1.785	0.745
Montane forest	9	1.874	0.724	0	0	0	9	1.874	0.724
Almaciga forest	9	1.597	0.549	6	1.431	0.697	15	2.082	0.535
Submontane dipterocarp forest	17	1.97	0.422	13	2.018	0.579	30	2.486	0.401
Lowland dipterocarp forest	14	2.118	0.594	12	2.37	0.892	26	2.804	0.635
Mixed dipterocarp forest	6	1.694	0.907	2	0.693	1	8	1.888	0.826
Mixed lowland dipterocarp forest	7	1.906	0.961	8	2.043	0.964	15	2.67	0.963
Plantation 1 (peniel)	7	1.82	0.8818	9	2.138	0.943	16	2.678	0.9097
Plantation 2 (Bunga)	6	1.733	0.943	4	1.386	1	10	2.254	0.952
Agro ecosystem 1 (Barangay lake)	6	1.529	0.7691	1	0	1	7	1.667	0.757
Agro ecosystem 2 (sebucal)	9	2.039	0.8535	8	1.625	0.635	17	2.451	0.6821
Agro ecosystem 3 (mansawan)	9	1.668	0.589	9	1.821	0.687	18	2.386	0.6037
Agro ecosystem 4 (peniel)	4	1.386	1	1	0	1	4	1.386	1
Agro ecosystem 5 (mamalad)	5	1.179	70.65	5	1.55	0.9421	10	1.956	0.7071
For all sites (pooled data)	26	2.59	0.5127	33	3.037	0.6315	59	3.174	0.405

existence of species that do not require them. Considering the scarcity of such microhabitats at high elevations, evolving a reproductive mode that would not require them, like developing directly into froglets and skipping the aquatic larval stage, would prove to be advantageous to a species if it is to successfully colonize the high altitude areas. This explains the dominance in the mossy and montane forests of the genus *Philautus*, a group of amphibians in which the eggs develop directly into froglets (Alcala and Brown 1998). *Philautus acutirostris* which topped the list of abundant species was encountered in almost

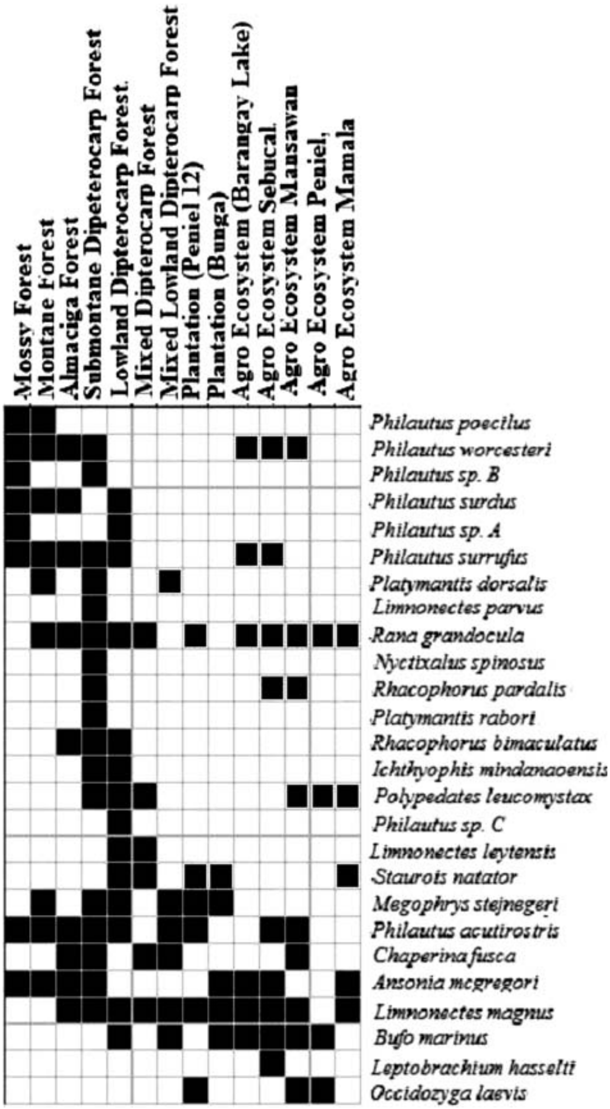

Fig. 2 Assemblage of amphibian species placed into sequence so that the sampling sites with the most similar proportions of certain taxa are together

all sampling sites in Mt. Malindang. This species with conservation status listed as vulnerable (IUCN 2007) was collected either from the ground or on the leaves of low-lying vegetation. *Philautus surrufus*, the second most abundant species takes the common name Malindang Tree Frog (Brown and Alcala 1994). This species was encountered in several vegetation types but was recorded to occur highest in the mossy forest. This species has been classified as endangered (IUCN 2007). *A. mcgregori* is a vulnerable species captured in various vegetation types including the highly disturbed agro ecosystems, but was recorded highest in abundance at the montane forest. This species was mostly collected

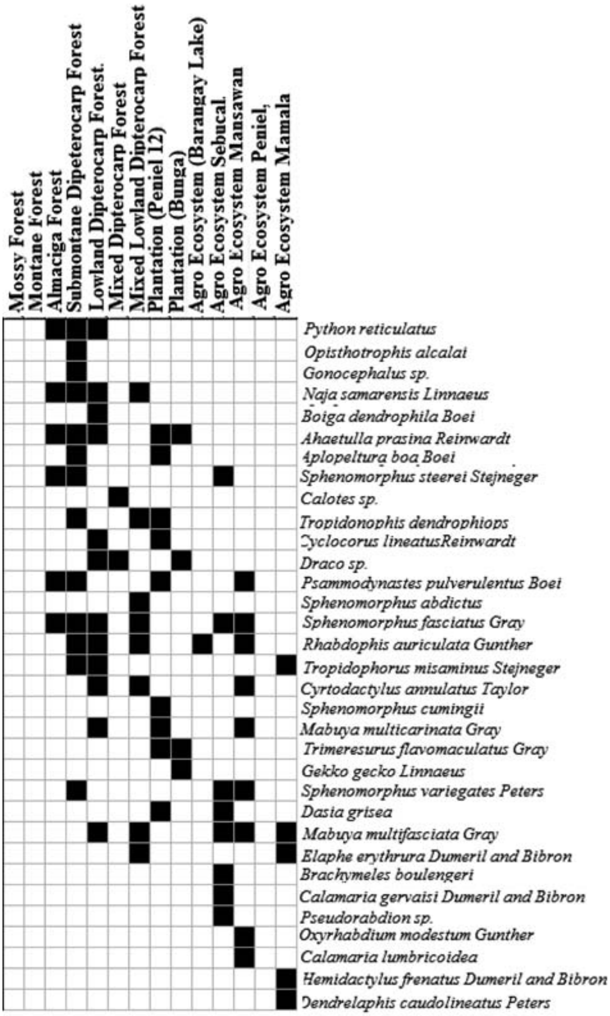

Fig. 3 Assemblage of reptilian species placed into sequence so that the sampling sites with the most similar proportions of certain taxa are together

from the forest floor. *Philautus worcesteri* is a Mindanao endemic that has also been classified as vulnerable by the IUCN (2007). Although it was also encountered in various vegetation types, the highest abundance recorded for this species was in the mossy forest.

In this study, three unidentified species of *Philautus* which are probably new species were found distributed in one to two sampling sites. Bossuyt and Dubois (2001) in their review of the specific taxonomy of the frog genus *Philautus* Gistel, 1848 found 143 types to be extant. They mentioned that from 1822 to 1999, 177 nominal species were either described as members of this genus, or of other genera but subsequently referred to this genus. Numerous species of this group remain to be described, particularly in Sri Lanka. Brown and Alcala (1994) reported that data on zonation and microhabitats in the mountains of the larger islands are available for eight Philippine species of *Philautus*. Most have

Table 7 Results of the rarefaction analysis on the abundance data

Site	Amphibians		Reptiles		Pooled	
	Observed	Expected (195)	Observed	Expected (32)	Observed	Expected (195)
A	8	8	0	0	8	8
B	9	9	0	0	9	9
C	9	9	6	6	15	15
D	17	17	13	13	30	30
E	14	14	12	12	26	26
F	6	6	2	2	8	8
G	7	7	8	8	15	15
H	6	6	9	9	15	15
I	5	5	4	4	9	9
J	6	6	1	1	7	7
K	9	9	8	8	17	17
L	9	9	9	9	18	18
M	4	4	0	0	4	4
N	5	5	5	5	10	10

Expected number of species was calculated against the largest sample size in parenthesis

been recorded from the mid-dipterocarp (300–500 m) through the montane forest that starts between about 800 and 2,000 m depending on the height of the mountain surveyed. For Philippine species of *Philautus*, density, based on sample sizes, is higher in the submontane and montane forest zones. This observation is in agreement with the reported zonal distribution of *Philautus* in Bornean forests, eight of 11 species of *Philautus* from Mt. Kinabalu, Mt. Mulu, Mt. Lumuko, and the Crocker range in Northwest Borneo being thus far recorded only from the montane zone, above the dipterocarp zone. The results of distribution of *Philautus* in this present study agree well with the above observations.

The endemic *Ichthyophis mindanaoensis* was found only in the submontane dipterocarp and lowland dipterocarp forests. This caecilian species is a lowland primary forest dweller and occurs at 600–850 masl (Alcala and Brown 1998; IUCN 2007). It is apparently common, but is very locally and patchily distributed. This species inhabits the rotting logs and decaying plant litter of the forest floor where it was captured during sampling. The adults and larvae were found in the mud in recently cleared agricultural fields at forest edge. IUCN has listed this species to be data deficient because there is still much to be learned about the status of this primitive amphibian.

Our data showed that except for the absence of reptiles in the montane and mossy forests, the majority of the amphibians and reptiles were found in more forested sites and in agroecosystem sites adjacent to forests. Herpetofauna flourished better in older forest than in young forest (Mitchell et al. 1997). The mossy, montane, almaciga, and submontane forests in this study were found to be old-growth forests. Likewise, the results analysed by seriation showed that the distribution of the herpetofauna seems to be correlated with elevation (Figs. 2, 3).

The present study agrees with the findings of Diesmos et al. (2003) who found that majority of the amphibians and reptiles in Balbalasang-Balbalan National Park (BBNP), Philippines are forest-restricted. They further reported that the distribution pattern of the herpetofauna of BBNP was positively related to elevation and the coinciding gradients of temperature and humidity. At lower elevations, forests are warmer and drier and support higher levels of reptile diversity and abundance in most species. At higher elevations, reptiles are scarcer and, when encountered, species are less abundant with fewer individuals encountered. This concurs with the absence of reptiles noted for the mossy and montane forests in the present study. Rahbek (1995) similarly reported that the trend of decreasing species richness with increasing elevation had been widely demonstrated for many taxa.

Since amphibians are moisture-sensitive (Heatwole 1982) and reptiles are moisture-selective organisms (Alcala 1976), an alteration of their suitable microclimate would have a negative impact on their populations. Ernst et al. (2006) found that South American anurans exhibited higher species richness in primary sites but in West Africa, anuran species richness did not differ between primary and exploited forest sites. In Mt. Malindang, except for two agroecosystem sites, amphibian species richness was high in primary and exploited forest sites but endemic amphibians especially the Mindanao endemics were mostly found in relatively intact forests.

Other sampling sites in this study have low to moderate numbers. For the reptiles, the more open canopy facilitates their basking behavior (Zug 1993). This was observed in this study where several individuals of *Mabuya multifasciata,* a non-endemic species that inhabits primary and secondary forests and can be found close to villages, were captured in agroecosystem sites while basking. Alcala et al. (2004) elucidated the effects of fragmentation and degradation of tropical rainforest on Negros Island (Philippines) on tropical herpetofauna. They found that the factors responsible for the loss of species appeared to be the removal of large trees where the decreased canopy cover caused physical changes, and forest fragmentation increased the edge areas.

It is interesting to note that the plantation forest site 1 had a herpetofaunal species richness of 16 while plantation forest site 2 had 9. This indicates that rehabilitating degraded areas through planting of trees could encourage wildlife in the area.

Results showed that the endemic herpetofauna in Mt. Malindang has to date been thriving relatively well. The relatively high level of endemism observed suggests that Mt. Malindang is favorable for amphibian speciation. The greater occurrence of endemics in the more highly forested sites indicates that forests indeed are important habitats for the herpetofauna, supporting several rare and restricted-range species.

In their study of the fauna of Mt. Malindang, Tabaranza et al. (2001) found fewer species with only 16 amphibians and 10 reptiles. They did not encounter the Malindang tree frog, *Philautus surrufus*. In this study, 17 species of amphibians and 31 reptiles found are additional records. Seven species of amphibians and eight reptiles earlier reported were not documented in this study. Considering the earlier record and the result of this study, Mt. Malindang has now an inventory of 33 species of amphibians and 41 reptiles. Since the earlier survey was done on the other side of the mountain range, it is possible that species not encountered in this study are not common in the present sites sampled but could be common elsewhere, or the present sampling might have simply missed them. Results of this study showed that Mt. Malindang has a higher total number of species compared with other mountains in Mindanao like Mt. Kitanglad (which still has patches of primary forest at 700 masl). A total of only 14 herpetofaunal species was recorded in Mt. Kitanglad (Heaney and Peterson 1992). The many sampling sites and representative elevations sampled may be contributing factors accounting for the higher number of species documented in this study. The sites with the highest number of threatened species were the forests at high elevation with varied layers of vegetation. It was also observed during the sampling that these were the sites which are less disturbed by humans due to their inaccessibility. Sexton et al. (1964) noted that the arrangement of vegetation in space and particularly its effect on the micro-environment is important in determining the local distribution of species. The structural complexity of forests provides the suitable micro-environmental conditions for the species. Alcala (1976) noted that the land vertebrates of the Philippines are generally distributed in areas covered by natural vegetation, especially forests. Amphibians due to their dependence on cutaneous respiration and sensitivity to dehydration require the general availability of continuous moisture, such as presented by tropical rainforests where the relative humidity is always at or near saturation. Zug (1993) reported that reptiles, even though not directly dependent on moisture, are affected by humidity, as shown by their frequent choice for moist or humid microhabitats in the tropical rain forests. Moisture conditions also affect the growth and differentiation of reptilian eggs and embryos. Forest sites with tall trees and high canopy cover assure the availability of environmental conditions required by a wide variety of land vertebrates.

Sites of community importance have higher habitat heterogeneity with wider surface areas and include higher number of species (Canova and Marchesi 2007). Our data demonstrate the importance of lush forests for the endemic and threatened fauna. The high diversity recorded for the herpetofauna is very encouraging considering that many areas in Mt. Malindang have already been converted for agricultural purposes. More extensive sampling in future studies could yield additional species.

Conclusion and recommendation

Mt. Malindang is an area of high herpetofaunal diversity. Given the high number of endemic and threatened species, Mt. Malindang is also a key area for conservation. The sampling sites at high elevation (submontane dipterocarp forest, almaciga forest, montane forest, mossy forest and two agroecosystem sites adjacent to forests) which showed high endemism, should be listed as priority areas for conservation. However, the fact that endemic and some threatened species are also found in the lowland forests (which are mostly threatened by habitat loss) shows the need to develop a conservation/management plan for the whole landscape.

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References

Alcala AC (1976) Philippine land vertebrates. New Day Publishers, Quezon City, 176 pp

Alcala A (1986) Guide to Philippine flora and fauna. Amphibians and reptiles. Natural Resources Management Center, Ministry of Natural Resources and University of the Philippines, Philippines, 195 pp

Alcala AC, Brown WC (1998) Philippine amphibians. An illustrated field guide. Bookmark, Inc, Makati City, Philippines, 116 pp

Alcala E, Alcala A, Dolino C (2004) Amphibians and reptiles in tropical rainforest fragments on Negros Island, the Philippines. Environ Conserv 31(3):254–261

Alcala AC, Alcala EL, Buot LE, Diesmos A, Dolar M, Fernando ES, Gonzales J, Tabaranza B (2006) Philippine biodiversity: ecological roles uses and conservation status. Plenary paper presented during the 28th National Academy of Science and Technology annual scientific meeting, NAST, Manila, 12–13 July 2006

Bossuyt F, Dubois A (2001) A review of the frog genus *Philautus* Gistel, 1848 (Amphibia, Anura, Ranidae, Rhacophorinae). Zeylanica 6(1):1–112
Brower JC, Kile KM (1988) Seriation of an original data matrix as applied to palaeoecology. Lethaia 21:79–93
Brown WC, Alcala AC (1978) Philippine lizards of the family Gekkonidae. Silliman University. Nat Sci Monogr Ser 1, Dumaguete City, Philippines, 131 pp
Brown WC, Alcala AC (1980) Philippine lizards of the family Scincidae. Silliman University. Nat Sci Monogr Ser 1, Dumaguete City, Philippines, 263 pp
Brown WC, Alcala AC (1994) Philippine frogs of the family Rhacophoridae. Proc Calif Acad Sci 48(10):85–220
Canova L, Marchesi M (2007) Amphibian and reptile communities in eleven sites of community importance (SCI): relations between SCI area, heterogeneity and richness. Acta Herpetol 2(2):87–96
Diesmos A, Brown R, Alcala A, Sison R, Afuang L, Gee G (2002) Amphibians and reptiles. Philippine biodiversity conservation priorities. A second iteration of the national biodiversity strategy and action plan. DENR-PAWB, Quezon City, Philippines, p 26
Diesmos A, Brown R, Gee G (2003) Preliminary report on the amphibians and reptiles of Balbalasang-Balbalan National Park, Luzon Island, Philippines. Sylvatrop. Tech J Philipp Ecosyst Nat Resour 13(1 and 2):63–80
Ernst R, Linsenmair K, Rodel M (2006) Diversity erosion beyond the species level: dramatic loss of functional diversity after selective logging in two tropical amphibian communities. Biol Conserv 133:143–155
Hammer Ø, Harper DAT, Ryan PD (2001) PAST: paleontological statistics software package for education and data analysis. Palaeontol Electron 4(1):9 pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm
Heaney LR, Oliver W (1997) Biodiversity and conservation in the Philippines: an introduction to a global priority. Philippine Red Data Book, Bookmark, Manila
Heaney LR, Peterson AT (1992) Inventory of the vertebrates of Mt. Kitanglad Nature Park. Final report for 1992. Field Museum of Natural History, USA
Heatwole H (1982) A review of structuring in herpetofaunal assemblages. In: Scott NJ Jr (ed) Herpetofaunal communities: a symposium of the Society for the study of Amphibians and Reptiles and the Herpetologists' League, August 1997. Wildlife Research Report 13. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, USA, pp 1–9
Heyer WR, Donnelly RW, McDiarmid RW, Hayek L, Foster MS (1994) Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institution Press, Washington, DC, 364 pp
Inger RF (1954) Systematics and zoogeography of Philippine amphibia. Fieldiana: zoology, vol 33, No. 4. Chicago Natural History Museum, Chicago, pp 185–531
Inger RF, Stuebing RB (1989) Frogs of Sabah. Sabah Parks. Publication No. 10. Kota Kinabalu, 120 pp
IUCN Red List of Threatened Species (2007) http://www.iucnredlist.org. Cited 15 Dec 2007
Krebs CJ (1989) Ecological methodology. Harper and Row, New York
Mitchell JC, Rinehart SC, Pagels JF, Buhlman KA, Pague CA (1997) Factors influencing amphibian and small mammal assemblages in central Appalachian forests. For Ecol Manag 96:65–76
Rahbek C (1995) The elevational gradient of species richness: a uniform pattern? Ecography 18:200–205
Sexton OJ, Heatwole H, Knight D (1964) Correlation of microdistribution of some Panamian reptiles and amphibians with structural organization of the habitat. Carrib J Sci 4:261–295
Sodhi NS, Koh LP, Brook BW, Ng PKL (2004) Southeast Asian biodiversity: an impending disaster. Trends Ecol Evol 19(12):654–660
Sodhi N, Bickford D, Diesmos A, Lee T, Koh L, Brook B, Sekercioglu C, Bradshaw C (2008) Measuring the meltdown: drivers of global amphibian extinction and decline. PloS ONE 3(2):e1636. www.plosone.org
Tabaranza BR, Tabaranza ACE, Bagaloyos AP, Dimapilis A (2001) Flora and fauna of Mt. Malindang Natural Park, Don Victoriano and Lopez Jaena, Misamis Occidental (final report). Haribon Foundation for the Conservation of Natural Resources, Inc., Diliman Quezon City, pp 34–36
Zug RG (1993) Herpetology: an Introductory biology of amphibians and reptiles. Academic Press, Inc, California, USA, 527 pp