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Amphibian diversity and endemism in the swamp forests of Agusan Marsh, Agusan del Sur, Philippines

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Abstract. Agusan Marsh, an ecologically significant wetland in the Philippines, consists of an extensive floodplain heavily dissected by numerous rivers and streams making it a very important source of freshwater, storing more than 15% of the nation's freshwater resource in the form of swamp forests. Since amphibians are very good indicators of climate change and ecosystem health, species diversity and endemism were assessed in sago swamp, terminalia, mixed swamp, and peat swamp forests in Agusan Marsh using a combination of cruising, pitfall trap and quadrat methods. Seventeen species with 41% endemism were recorded. Of the seven endemic species, five are Mindanao endemic. The two undescribed species of *Oreophryne* and one *Philautus* could be new species and were observed in the terminalia, sago, and mixed swamp forests but not in the peat swamp forest. The peat swamp forest where the invasive *Rhinella marina* was abundant, had the least species richness owing to habitat disturbance brought about by human encroachment. The highest species richness and abundance were observed in the terminalia forest primarily due to the presence of suitable microhabitats. Four vulnerable species were recorded in the marsh. Most of the vulnerable and endemic species were documented in the terminalia and mixed swamp forests. High diversity and more or less even distribution were observed in all sites. Three amphibian species are considered socio-economically important and are hunted for food and bait for fish. The presence of endemic and vulnerable species indicates that Agusan Marsh is a key conservation site. Logging and widespread mining, discharging tons of mine tailings into the rivers which find their way into the swamp forests are just some of the threats to the amphibians in the marsh. Conservation action is necessary to protect the endemic and vulnerable species in the swamp forests and the Agusan marsh in general.

Key Words: Conservation, peat swamp, terminalia, vulnerable, wetland.

Introduction. Agusan Marsh, the biggest marsh in Southeast-Asia, stores more than 15% of the nation's freshwater resource in the form of swamp forests. Its major features are the lakes, swamps and peat forests. The presence of unique and pristine habitat types like the Sago swamp, Peat swamp, Mixed-swamp forests and the diverse biological and endemic species make Agusan Marsh an ecologically significant wetland in the Philippines. This unique marshland hosts and protects some of the world's rare, threatened and endangered flora and fauna. The Agusan Marsh is a protected area, officially called the Agusan Marsh Wildlife Sanctuary (AMWS). As protected area, the goal is sustainable development by protecting and utilizing local biological treasures in ways that do not diminish the variability of genes and species or destroy important habitat and ecosystem (DENR-IPAS 2003). Wetlands have historically been considered impediments to development, to be drained, filled, and converted to a "useful" condition. The enormous value of wetlands, from providing natural flood control and water filtration services to supporting populations of fish and wildlife on which people depend for food, employment, and recreation, is increasingly appreciated. The AMWS which was given Ramsar site status in 1999 covers an area of 14,835.989 hectares (UNESCO 2010).

Amphibian and reptile communities are known to be sensitive to environmental changes and are easily affected by fragmentation, logging and changes in microclimatic variables through a disturbed gradient in the habitat structure (Alcala & Custodio 1995). Fragmentation and habitat loss, which are now experienced in Agusan Marsh, can affect amphibian assemblages (Lehtinen et al 1999). However, researches on amphibians from North America relative to urbanization gave a negative response (Scheffers & Paszkowski 2012). Landscape disturbance can reduce live and detrital vegetation, which can be important to foraging, retreat, and burrowing sites for amphibians (Naughton et al 2000). Amphibians are the most vulnerable organisms that are first to suffer the consequences of environmental threats that may go initially undetected by humans because of their being nocturnal (Hickman et al 1993). In Southern Brazil, expansion of pine diminishes the anuran richness and abundance in ponds and it changes the anuran composition (Machado et al 2012). Amphibians are especially susceptible to changes in their natural environment brought on, for example, by pollution and climate change which can lead to increased ultraviolet radiation and temperature, and changes in humidity (Bickford et al 2010; Pounds et al 2006; Semlitsch 2003).

The Philippines has a total of 24 threatened amphibians of which seven are critically endangered, six species are endangered and eleven species are vulnerable (Heaney 2005). Threats to amphibians can be attributed to over hunting for food as an additional income among Manobos, the indigenous people in the area; chemical contamination and pollution of streams and rivers from mine tailings; pesticides and herbicides run-off; draining of water for agriculture purposes and introduction of alien and invasive species of amphibians (DENR-IPAS 2003).

Agusan Marsh plays a major role in providing protection, ecological balance, livelihood and other amenities to local communities. The Global Amphibian Assessment which is an ongoing project since 2004 has declared Agusan Marsh Wildlife Sanctuary, as one of the major sites for biodiversity conservation in the country (Primavera & Tumanda 2006). The moist condition of the swampy forests in Agusan Marsh, the presence of different types of water ways and the abundant species of insects favor the existence of amphibians in the marsh (Varela & Gapud 2007). Most of the amphibians in the Philippines are understudied and poorly known since only few amphibian surveys are conducted. Data on amphibians in swamp forests in particular, are scanty due to limited studies in swampy forests. The known data for Agusan Marsh are those of DENR-IPAS (2003) which recorded a total of 21 amphibians and Bastian & Ibanez (2007) who reported 12 species of amphibians of which seven are Philippine endemic. Habitat requirements and population estimation are unknown. Information gathered from this study can contribute to the existing bulk of knowledge on amphibians in swamp forests. This study assessed the amphibians of Agusan Marsh in terms of species composition, diversity, endemism, abundance, and threats. This information is important towards the conservation and management of the Agusan Marsh.

Material and Method

The study area. Agusan Marsh is located in the province of Agusan del Sur, Northeastern Mindanao, Philippines between 125^0 38` and $125^0$ 05` North Latitude; 8^0 07` and $8^0$ 27` Longitude in the middle of Agusan River basin. It extends from Barangay Causwagan of Talacogon in the North to Barangay San Gabriel of Veruela in the south and covers an area of 65,806 hectares of which 19,196 hectares is a proclaimed sanctuary extending from Lake Lumbao near the municipality of Talacogon in the North to the municipality of Vereula, Agusan del Sur to the South (Figure 1). It covers a portion of eight municipalities particularly 64 barangays (Primavera & Tumanda).

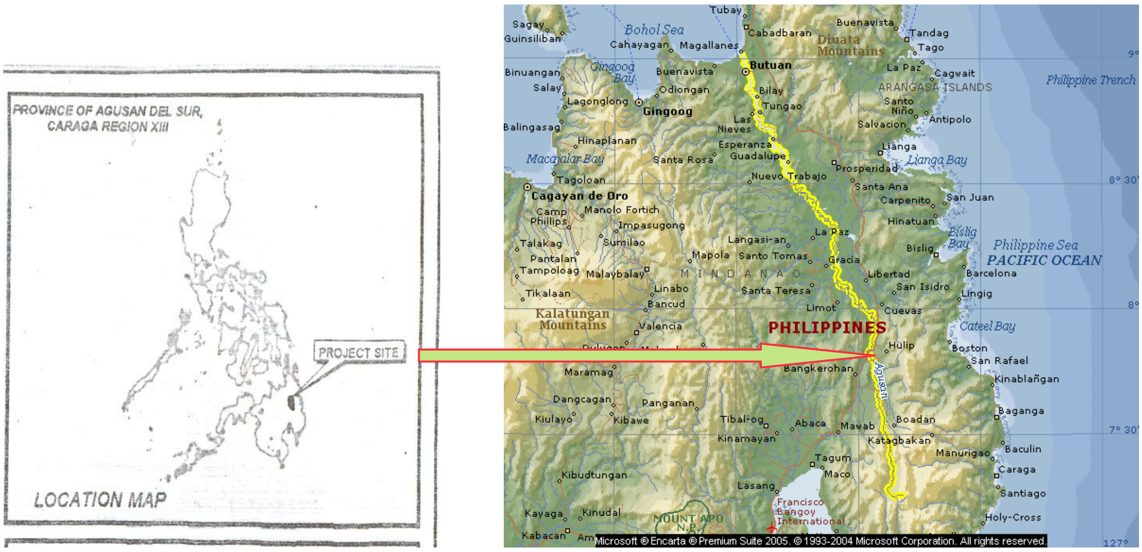

Figure 1. Map showing the location of Agusan Marsh in Mindanao, Philippines.

Sampling sites. Four sampling sites were established in this study (Figure 2). Sampling site 1 (20-24 masl), Sago swamp forest (Figure 3) is situated in Sitio Kaliluan, Poblacion Bunawan, Agusan del Sur at 08^0 09.825' North latitude and 125^0 57.637' East longitude. It is about 300 hectares and has a relatively flat slope. Sampling was done for 10 days on September 14 to September 19, 2005 and on November 14 to November 17, 2005. The sampling area, constantly flooded with water, has series of brooks and streams. Water level ranged from 9 to 15 inches.

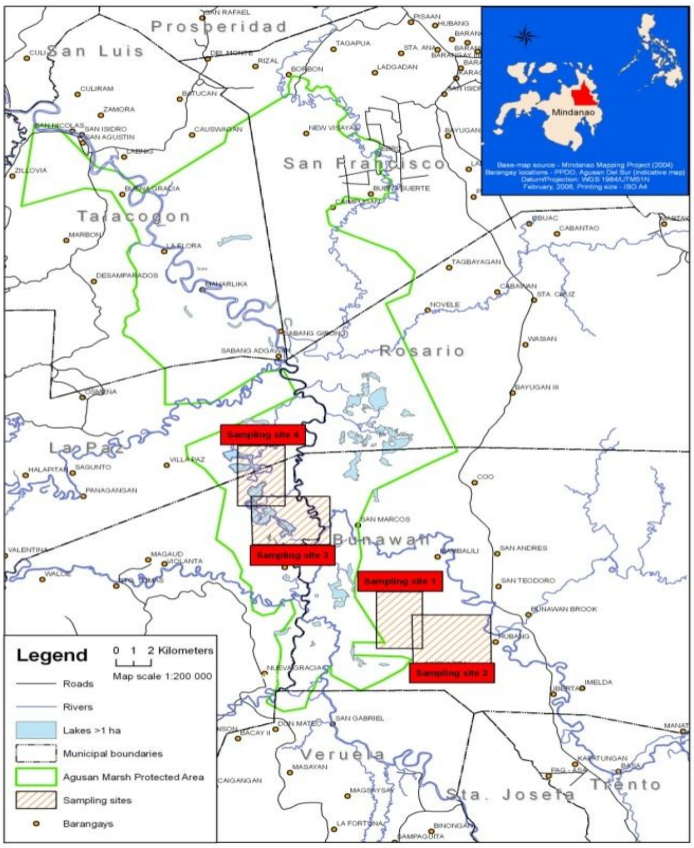

Figure 2. Map of Agusan del Sur showing the four sampling sites.

Figure 3. Sago Forest (Sampling site 1).

The Sago swamp forest is a secondary forest dominated by *Metroxylon sagu* or "sago" under the Palm family or Arecaceae. There were other trees spotted in the area like *Ficus nota* (Blanco) Merr. under Family Moraceae. Height of the emergent trees ranged from 5 to 23 meters and the height of canopy ranged from 1 to 9 meters while highest diameter at breast height (DBH) of emergent trees is 45 centimeters. The canopy vines were *Mikania cordata* (Burm. f.) B. L. Rob and *Stenochlaena palustris* (Burm. f.) Bedd, which is about 60% and canopy epiphytes of Family Poaceae. Some of the known understory and ground cover plants were *Paspalum conjugatum* P. J. Bergius of Family Poaceae. The Indian rubber tree (*Ficus elastica*) is also present. Pitcher plant was found; moss density was about 40%; leaf litter is 90% and the depth of humus cover is about one foot with sandy loam soil; fallen logs were minimal caused by storm. The distance from the sampling site to anthropogenic clearing of a small scale rice plantation and human settlement was approximately 50 meters. An abandoned slash and burn farm was observed at the periphery of the sampling site. Regrowth of trees, grasses and sedges were observed.

Sampling site 2 (27-30 masl), the Terminalia Forest, is situated at Sitio Kaliluan, Poblacion Bunawan, Agusan del Sur (Figure 4) situated at 08^0 09.825' North latitude and 125^0 58.044 East longitude. Sampling was done for 10 days on September 14 to September 19, 2005 and November 18 to November 21, 2005. Most of the area was flooded with water and a stream is found within the sampling area. Terminalia Swamp Forest is a flat primary forest dominated by *Terminalia copelandii* Elm. and *Terminalia calamansanay* Rolfe under Family Combretaceae. Height of emergent tree ranged from 10 to 35 meters and the height of canopy ranged from 5 to 15 meters while the DBH of emergent trees is 80 cm. It has a plant community of Rhamnaceae, *Zizyphus talansi* (Blanco) Merr.; Fabaceae; Dilleniaceae (*Dillenia philippinensis* Rolfe); Lythraceae (*Lagerstroemia speciosa* L.) Pers; *Syzyium ellipticum* (Merr.) Merr & Ferry under Myrtaceae family, *Mitragyna rotundifolia* (Roxb.) Kuntze under family Rubiaceae; Lauraceae (*Crytocarya lauriflora* (Blanco) Merr.), *Ficus* under Moraceae family; and Pandanaceae (*Pandanus sp*.). Canopy epiphytes, canopy vines, understory plants, and rare patches of grasses or sedges were observed.

Fruit trees and mosses of about 10% cover were present. Depth of humus cover is about 4 inches with alluvium and clay loam soil type. There were few logs; no exposed rocks. The site was 30 meters away from the river and the flowing water of the brook is within one of the quadrates established in the site. The distance from the sampling site to anthropogenic clearing and human settlements was about 50 meters. Slash and burn and small scale farming can be observed few meters away from the sampling site.

Figure 4. Terminalia Forest (Sampling site 2).

Sampling site 3 (10-14 masl), the Peat Swamp Forest (Figure 5), is situated at Sitio Panlabuhan, Poblacion Loreto, Agusan del Sur (Figure 2) at 08^0 14.276' North latituide and 125^0 52.664' Sampling was done for 12 days on September 21 to September 27, 2005 and November 22 to November 27, 2005. The site comprised a disturbed secondary forest area since it is near human settlements and an undisturbed primary forest area.

Figure 5. Peat Swamp Forest (Sampling site 3).

The Peat Swamp forest is dominated by Rubiaceae (*Nauclea orientalis* (L.) L.) and Lecythidaceae (*Barringtonia racemosa* (L.) Spreng.). Height of emergent trees ranged from 5 to 12 meters and canopy ranged from 1 to 5 meters while the highest DBH of emergent trees is 40 cm. It has a plant community of *Nauclea*, Rubiaceae (*Mitragyna rotundifolia* (Roxb.) Kuntze). Canopy vines, canopy epiphytes, understory plants like water hyacinth (*Eichornia crassipes* (Mart.) Solms of Family Pontederiaceae were present while grasses and sedges like *Echinochloa stagnina* (Retz.) P. Beauv.; *Arundo donax L.*; *Saccharum spontaneum L*; *Paspalum conjugatum* P. J.Bergius under Poaceae family and *Cyperus malaccensis* Lam, about 8 meters tall dominate the area. Moisture was 100%; fallen logs were absent. River, pond, swamp, creek and lake were present near the sampling site. Anthropogenic clearing was absent because houses are floating and the main source of income is fishing. The area has an alluvium and clay loam type of soil.

Sampling site 4, the Mixed Swamp Forest, is situated in Sitio Panlabuhan, Poblacion Loreto, Agusan del Sur (Figure 6) at 08^0 15.046' North latitude and 125^0 52.381' East longitude at an elevation of about 12-16 masl. Sampling was done for 12 days on September 21 to September 27 and November 22 to November 27, 2005. Sampling site 4 has a flat slope. It is a disturbed secondary forest. The Mixed Swamp Forest is largely composed of *Barringtonia racemosa* (L.) Spreng and *Nauclea orientalis* regular. The height of emergent trees ranged from 12 to 20 meters and canopy ranged from 2 to 5 meters while highest DBH is 60 cm. Its emergent trees are of Family Rubiaceae and its canopy was dominated by Family Myrtaceae. Canopy vines, understory plants like ferns, water hyacinth *Eichhornia crassipes* (Mart.) Solms under Pontederiaceae, water lily, Pistia stratiotes L. under Araceae family and canopy epiphytes were observed. On site disturbances were observed such as farming corn, and kaingin on the edges near the bank of the river and Subaon Creek. Anthropogenic clearing was about 20 to 30 meters away from the sampling site. There were no exposed rocks; fallen logs were about 20%; the area has clay loam or loose soil type; humus cover was about 7 feet and leaf litter cover was 4 centimeters; mosses were abundant on body of trees or tree trunks about 70%; ficus (*Ficus balete)* Merr. was 80% abundant.

Figure 6. Mixed-swamp Forest (Sampling site 4).

Collection of samples. Quadrate, cruising, and pitfall trap methods were used. These techniques employ intensive sampling of arboreal, surface and subterranean strata in the chosen sites. Five quadrates of about 20x20 m were laid down randomly in each sampling site.

In the cruising method, four researchers walked through study sites thoroughly searching for amphibians. Forest floors, fallen logs, tree holes, tree buttresses, barks, leaves, ferns, shrubs, vegetation debris and other possible microhabitats were searched for amphibian species. All amphibians encountered in every sampling activity were collected. The pitfall trap method was also used in this study to determine species richness at a sampling site and to detect presence of burrowing frogs. Several holes measuring about 15x15 inches and about one meter deep with wider bottom diameter resembling an Erlenmeyer flask to keep animals from crawling out of the trap were dug on the ground. The trap was fenced with 30x60 inches black plastic garbage bag to guide the amphibians into the trap when jumping. The trap was examined daily for any trapped amphibians. All amphibians encountered were placed in specimen bags and brought to the camping site for recording of body weight and morphometrics, documentation, identification, and tagging before releasing them to identify recaptured species (capture-mark-release technique). Collection was done from 600 to 1000 hours and 1900 to 2400 hours.

Identification and processing of amphibians. Collected samples were identified following the available guides and taxonomic literature on Philippine amphibians based on the works of Inger (1954), Alcala & Brown (1998), and Global Amphibian Assessment (2012). The list of endemic species was also based on these published works. Morphometrics were measured using a vernier caliper while body weight was taken using a Pesola spring balance. Species were identified right away and were tagged and released back into the field. One to two voucher specimens were prepared especially for species not identified in the field. They are stored in the Natural Science Museum of the Mindanao State University-Iligan Institute of Technology, Iligan City.

Determination of socio-economic importance and threats. Determination of socio-economic importance of amphibians and threats to the Agusan marsh and the amphibians in particular was based on key information interviews and direct observations.

Results and Discussion

Species composition and abundance. Seventeen species of amphibians belonging to Families Bufonidae, Ranidae, Microhylidae and Rhacophoridae were documented (Table 1). Highest species richness (17) and abundance were observed in the Terminalia forest. The frequent rainfall increases the density of food resources of anurans, probability of breeding, larval survival and juvenile recruitment (Gray et al 2004) and decreases the possibility of desiccation in the Terminalia forest. This site was observed to have high vertical heterogeneity with varied tree species. High diversity and mosaic distribution of habitats lead to the continuous occurrence and high relative abundance of herpetofauna (Petrov 2007). A landscape composed of a mosaic of forest and open habitats surrounding wetlands would hold the highest diversity of frog species (Gagne & Fahrig 2007). Sites of community importance have higher habitat heterogeneity with wider surface areas and include higher number of species (Canova & Marchesi 2007). The closed canopy cover and the presence of native vegetation in the Terminalia forest is favorable to amphibians as it offers a more humid environment necessary for their survival. Lemkert et al (2009) reported that the presence of native vegetation allows most species of frog to increasingly survive. The study of Jofre et al (2010) from the central region of Argentina shows that the highest relative abundance of anurans was detected in the area that provides stable food and refuge having permanent reservoir from precipitation. All the species found in the four sampling sites were documented in the Terminalia forest.

Table 1

Species composition, number of individuals and relative abundance in the different sampling sites

Anurans	*Sampling sites*				*Total*
	1	*2*	*3*	*4*	
	Sago Swamp Forest	*Terminalia Forest*	*Mixed Swamp Forest*	*Peat Swamp Forest*	
Bufonidae Family					
Rhinella marina (Linnaeus 1958)	0 (0.0%)	16 (4.22%)	0 (0.0%)	68 (28.45%)	84 (8.26%)
Microhylidae Family					
Kaloula baleata (Muller 1833)	1 (0.48%)	4 (1.06%)	0 (0.0%)	0 (0.0%)	5 (0.49%)
Kaloula conjuncta meridionalis (Inger 1954)	0 (0.0%)	3 (0.79%)	2 (1.04%)	2 (0.84%)	7 (0.69%)
Oreophryne sp.1	4 (1.93%)	10 (2.64%)	1 (0.52%)	0 (0.0%)	15 (1.47%)
Oreophryne sp. 2	1 (0.48%)	2 (0.53%)	3 (1.56%)	0 (0.0%)	6 (0.59%)
Ranidae Family					
Fejervarya cancrivora (Gravenhorst 1829)	49 (23.67%)	108 (28.50%	51 (26.56%)	30 (12.55%)	238 (23.40%)
Fejervarya limnocharis (Gravenhorst 1829)	24 (11.59%)	62 (16.36%)	18 (9.38%)	19 (7.95%)	123 (12.09%)
Limnonectes leytensis (Boettger 1893)	27 (13.04%)	62 (16.36%)	61 (31.77%)	60 (25.10%)	210 (20.65%)
Limnonectes parvus (Taylor 1920)	2 (0.97%)	12 (3.17%)	3 (1.56%)	5 (2.09%)	22 (2.16%)
Occidozyga laevis (Gunther 1858)	65 (31.40%)	55 (10.51%)	14 (7.29%)	28 (11.72%)	162 (15.93%)
Rhacophoridae Family					
Philautus sp.	5 (2.42%)	1 (0.26%)	1 (0.52%)	0 (0.0%)	7 (0.69%)
Philautus acutirostris (Peters 1867)	0 (0.0%)	5 (1.32%)	2 (1.04%)	3 (1.26%)	10 (0.98%)
Philautus poecilus (Brown & Alcala 1994)	5 (2.42%)	1 (0.26%)	1 (0.52%)	0 (0.0%)	7 (0.69%)
Polypedates leucomystax (Gravenhorst 1829)	10 (4.83%)	10 (2.64%)	25 (13.08%)	12 (5.02%)	57 (5.60%)
Rhacophorus appendiculatus (Gunther 1858)	7 (3.38%)	15 (3.96%)	3 (1.56%)	4 (1.67%)	29 (2.85%)
Rhacophorus bimaculatus (Peters 1867)	3 (1.45%)	2 (0.53%)	1 (0.52%)	2 (0.84%)	8 (0.79%)
Rana everetti (Boulenger 1882)	4 (1.93%)	11 (2.90%)	6 (3.13%)	6 (2.51%)	27 (2.65%)
Total number of individuals	207 (20.35%)	379 (37.26%)	192 (18.87%)	239 (23.50%)	1017
Total number of species	14	17	15	12	17

At the periphery of this forest, slash and burn farming, rice farming, and fishpond were noted. With these activities, insect population is expected to increase with the disturbance so food available for amphibians also increases which favors survival of frogs particularly the introduced species. Invasive species flourish and dominate the area due to the absence of natural predators (Reh & Seitz 1990).

The mixed swamp forest was found to be next to the Terminalia forest in terms of species richness (15) but abundance is very low. The forest floor was observed to be flooded with deep water particularly during high rainfall where the water stagnates for specific period of time. This result in the abundance of undergrowth dominated by thick water hyacinth that makes it difficult for frogs to survive due to a very close leaf arrangement and thick fibrous roots during high water level. When the water abruptly subsides, the decaying bodies of plants on the forest floor deter the frogs from staying possibly due to the toxins emitted by the decaying water hyacinths. Frogs in this site seek refuge and thrive in *Mikamia cordata* of Family Convulvulaceae where they cling from the ground up to the trees, some of them thriving on tall grasses. This was particularly observed in the smallest tree frog in the marsh under genus *Oreophryne*. The mixed swamp forest is far from human settlements and near the lakes with fishes and abundant birds including migratory birds that feed in the marsh. The area has an exposed upper canopy layer which gives easy access for predators like birds and snakes allowing frog species fewer retreat. The presence of a great number of predators limits the number of frog individuals in this site. The alteration of its habitat condition from constant flooding and storms destroys some of the vegetation reducing its microhabitats. Trees that are permanently submerged in water experience this natural disturbance caused by strong floods destroying some of these trees due to strong water currents.

Fourteen species and low abundance of anurans were recorded in the sago swamp forest. The elongated large leaves of sago plants (*Metroxylon* species) are provided with sharp spiny thorns that accumulate on the forest floors. This site is very difficult to penetrate and does not favor a good microhabitat for frogs considering their smooth, sensitive skin that can be easily damaged by the spines of sago leaves. Only highly adapted or tolerant species may be able to cope with this condition (Miller et al 2001). Individuals that settle in less suitable environment leave fewer surviving offspring than those choosing better habitats (Nuñeza et al 2010).

The lowest species richness was observed in the Peat swamp forest. The structural make-up of this forest is less complex that could possibly induce a microclimate that is less conducive for the survival of some species. This site was dominated by grasses and light penetration is maximum giving less suitable microhabitats. The tree stands in this site are less and widely spaced thus creating a low canopy cover. Canopy cover is very important for amphibians being exothermic organisms. Intense sunlight is not suitable for them since they need their skin to be constantly moist so they keep on staying in water exposing themselves to predators in water, the fishes. Only those organisms with wide range of tolerance can adjust in this habitat like the generalist feeder *Ferjervarya cancrivora*, the water loving puddle frog, *Occidozyga laevis* and *Limnonectes leytensis* that naturally thrive in grasses that are partially submerged in water which are abundant in this site.

The marsh particularly the Peat swamp and Mixed-swamp forests having the lowest elevations, serve as water catchments. These swamp forests receive water from surrounding barangays containing chemical residues from agriculture and gold mining. Small-scale gold mining is rampant in Agusan Province. The permeable skin of frogs is very sensitive to pollutants like these and this can possibly explain the low species richness in the peat swamp forest and the low abundance in the mixed swamp forest. Such substances, including pesticides, may have a hormone-disruptive effect (Khan & Law 2005). Furthermore tadpoles, as filter-feeders, stabilize water quality of ponds and consequently their disappearance may have a negative impact on ecosystems as well as living conditions for rural human populations (Mohneke 2011; Sanderson & Wassersug 1990).

The low species abundance in Sago and Mixed swamp forests could be attributed to the similarity in their physical condition that prevents movements of frogs, high diversity of vertebrate predators such as birds, reptiles particularly snakes, and fishes that eat eggs and larvae of frogs, and other physical factors that limit the abundance of species. A study on the importance of predatory fish on structuring amphibian communities within Ohio region revealed that it has a negative effect (Porej & Hetherington 2005). The seasonal flooding in the sago and mixed swamp forests, bringing agricultural pollutants from fertilizers and pesticides greatly affect frog's survival. Geoffrey et al (2011) reported that malathion, an agricultural chemical, could have significant effects on anuran populations and communities. Nitrate might potentially mediate such effects in some species. Flood also allows creeping plants to thrive in bodies of trees competing with trees for photosynthesis resulting to the stunted growth of some of these trees. Because of this the number of microhabitats at the lower portion of the forest decreased as shown by the absence of ground dwelling species in these sites.

Sago and Mixed swamp forests have very closed canopy cover preventing light to penetrate. Studies done in Northeastern Connecticut, USA, found that open canopy specialists tended to be absent in heavily shaded wetlands compared to canopy generalist species which is less affected by low light levels. Canopy may be an important determinant of amphibian diversity patterns across wetlands because species differ in their sensitivity to changes in canopy (Skelly et al 2005).

Occidozyga laevis was the most abundant (65) anuran in Sago Forest since the area is surrounded with tall grasses in stagnant water which is their natural habitat. *Fejervarya cancrivora* was the most abundant anuran in the Terminalia Forest. This site is near human habitation where this was introduced since this is used as food by the local populace. *Rana limnonectes leytensis* was the most abundant (61) anuran in the mixed swamp forest due to the presence of thick leaf litter on the forest floor which serves as their microhabitat. *Rhinella marina* with its ability to survive in a nutrient poor and acidic soil was the most abundant (68) anuran in the peat swamp forest. *F. cancrivora* turned out to be the most abundant anuran species in Agusan Marsh. This is an exotic species in the Agusan marsh which is probably a threat to the native fauna (IUCN Red List 2012) and found to be very productive, adaptive and competitive in terms of food and habitat. It is said to be a generalist feeder (IUCN Red list 2006). Alcala & Brown (1998) reported that this species can even tolerate saline water and inhabit ditches, ponds, brackish fishponds, rice fields and mangroves. According to Edelstein-Keshet (1988), populations with elevated abundance may be less stable, particularly if they exceed their carrying capacity or have high intrinsic rate of increase. The local people constantly harvest *F. cancrivora* for food and this could regulate the population of this species, allowing it to maintain its carrying capacity.

L. leytensis ranked next in abundance. The sampling sites are swampy with the presence of creeks, lakes, ponds and riversides which are their favorable habitats. *L. leytensis* thrives in water logged forest floors, the abundant rotting leaves and leaf litters in all the sites. *O. laevis* ranked third in terms of relative abundance due to the presence of water around the sites and rice fields near the sites.

In Sago forest, *Rhinella marina* is absent due to the distance of this forest from human settlements. The presence of thick thorny dead leaves of sago plant is inhospitable to this toad. *P. acutirostris* is not present due to the absence of low-lying vegetation which is its microhabitat. Nuñeza et al (2010) reported that *P. acutirostris* is the most abundant species observed in Mt. Malindang, Philippines due to the presence of low-lying vegetation. In the Peat swamp and Mixed-swamp forests the muddy and watery forest floor prevents the burrowing frog, *K. baleata* to inhabit the area.

The abundance of amphibians in an area depends on the ability of amphibian species to escape predation. The presence of dermal toxins in *Rhinella marina* and the cryptic colorations of *Rana* or *Fejervarya* and *Limnonectes* to efficiently escape predators make them more abundant than other frogs. Studies done in the Southern High Plains revealed that more active tadpoles of Spadefoot are conspicuous and vulnerable to predation (Alford & Richards 1999). A species having a wide tolerance for a particular factor is likely to have big population size or a wide distribution or both (Alcala 1976).

The most represented family in Agusan Marsh is Family Rhacophoridae (Figure 7) because the frogs in this family commonly live in trees and bushy or shrubby habitats.

They reproduce in trees and low lying vegetation in the marsh. Their eggs are laid in foam above a water source so the tadpoles fall into the water once they hatch (Zweifel 1998). This suitable condition is provided by the marsh.

Figure 7. Frog species belonging to Family Rhacophoridae.

Endemic and threatened amphibians in Agusan Marsh. A 41% endemism was recorded in the marsh (Table 2).

Table 2

Number of individuals, endemic, and threatened species in the four sampling sites

Anurans	*Sampling sites*				*Total*
	1	*2*	*3*	*4*	
	Sago Swamp Forest	*Terminalia Forest*	*Mixed Swamp Forest*	*Peat Swamp Forest*	
Total number of individuals	207	379	192	239	1017
Mean	12.18	22.29	11.29	14.06	59.82
Standard deviation	18.80	30.55	18.32	21.13	76.74
Total number of species	14	17	15	12	17
Total number of endemics	5	7	6	6	7
Percentage of endemic species	29.41	41.17	35.29	35.29	41.17
Total number of threatened species	3	4	4	3	4

Of the seven endemic species recorded, four are Mindanao endemic. The small *Philautus* sp. with snout-vent-length (SVL) of 20.26 mm, the much smaller *Oreophryne* sp. 1 with SVL of 16.29 mm and *Oreophryne* sp. 2 which was much smaller with SVL of 14.9 mm were the least abundant. These very rare endemic species are probably new species.

Oreophryne sp. 1 is very much similar to *Oreophryne annulata* but has smaller SVL measurement. It has a unique calling sound and body coloration. Bastian & Ibanez (2007) reported six species of Philippine endemic frogs out of the 12 species identified in the Sago forest. The present study recorded a higher species richness and endemic species in the sago forest.

The low percentage of amphibian endemic species in Agusan Marsh could be further threatened by the seasonal flooding and the presence of agricultural pollutants and mine tailings. Frogging or frog collection for fish bait and food could be detrimental to the rare endemic species with limited abundance.

Four vulnerable species were recorded in the marsh *L. parvus, P. acutirostris, P. poecilus and R. bimaculatus*. Three of these are endemic species. Table 3 shows the habitat, distribution, and conservation status of the amphibians found in Agusan Marsh.

Table 3

Habitat, distribution status and conservation status of anurans

Taxon (Common name)	*Local distribution and conservation status*	*Habitat*	*Distribution status (IUCN, 2012)*	*Conservati-on status (IUCN, 2012)*
Rhinella marina (Giant Toad)	Introduced; abundant in sites near habitation & absent in pristine sites	Terrestrial, freshwater	Introduced; common	Least concern
Kaloula baleata (Muller's Narrow mouthed Toad)	Native; rare	Terrestrial, freshwater	Non endemic; common	Least concern
*Kaloula conjuncta meridionalis (*Muller's Narrow mouthed Toad)	Native; rare	Terrestrial, arboreal	Mindanao endemic; common	Least concern
Oreophryne sp.1 (believed to be new to science)	Probably new species; rare	Arboreal	Rare	-
Oreophryne sp. 2 (believed to be new to science	Probably new species; rare	Arboreal	Rare	-
Occidozyga laevis (Puddle Frog)	Native; abundant	Terrestrial, freshwater	Non-endemic; Native; Common	Least concern
Fejervarya cancrivora (Asian Brackish Water Frog)	Introduced; abundant	Terrestrial, freshwater	Non-endemic; native, common	Least concern
Fejervarya limnocharis (Common Pond Frog)	Native; less abundant	Terrestrial freshwater	Non-endemic; Native, Common	Least concern
Limnonectes parvus (Phil. Small-disked frog)	Native; rare	Terrestrial, freshwater	Mindanao endemic, rare	Vulnerable B1a(iii)
Limnonectes leytensis (Swamp Frog)	Native; abundant	Terrestrial, freshwater	Philippine endemic; rare	Least concern

Taxon (Common name)	Local distribution and conservation status	Habitat	Distribution status (IUCN, 2012)	Conservati-on status (IUCN, 2012)
Philautus sp. (believed to be new to science)	Probably new species	Shrub, tree seedlings	Rare	No data
Philautus acutirostris (Pointed-snouted Tree Frog)	Native; rare	Terrestrial, arboreal	Mindanao endemic; rare	Vulnerable B1ab(iii)
Philautus poecilus (Mottled Tree Frog)	Native; rare	Terrestrial, arboreal	Mindanao endemic; rare;	Vulnerable B1ab(iii)
Polypedates leucomystax (Four-lined Tree Frog)	Native; abundant	Arboreal	Non-endemic; native, common	Least concern
Rhacophorus appendiculatus (Rough-armed Tree Frog)	Native; rare	Arboreal, terrestrial, freshwater	Non-endemic; rare native, uncommon	Least concern
Rhacophorus bimaculatus (Asiatic Tree Frog)	Native; rare	Arboreal, terrestrial, freshwater	Philippine endemic; uncommon	Vulnerable B1ab(iii)
Hylarana everetti (Everett's Frog)	Native; rare	Arboreal	Mindanao endemic; uncommon	Data deficient

Table 4 shows high diversity in the four sampling sites. A slightly higher diversity was recorded in the Terminalia forest (H'=2.467). Rainfall is high in Terminalia making the area more productive. The presence of agricultural disturbances around the Terminalia forest gave rise to the abundance of *F. cancrivora,* a newly introduced species in agricultural areas near the swampy forests. This species explosively breeds and is competitively dominant due to the absence of its natural predator (Gray et al 2004). Floodplains and large woody debris in the Terminalia forest are abundant. Active floodplain, vegetated islands and large woody debris are important, directly and indirectly, in maintaining both habitat and amphibian diversity and density (Klaus et al 2006).

Table 4

Species diversity and evenness of anurans in the four sampling sites in Agusan Marsh

	Terminalia Forest	*Sago Forest*	*Peat-Swamp Forest*	*Mixed Swamp Forest*
Species	17	14	12	15
Individuals	379	207	239	192
Dominance	0.112	0.143	0.139	0.125
Shannon H'	2.467	2.243	2.231	2.258
Evenness	0.621	0.628	0.665	0.638

The existence of many humid environments and microclimates that acts as ecological refuge permits the presence of a large number of frog species (Pefaur & Rivero 2000). Terminalia has permanent breeding sites for tadpoles. Tadpoles having permanent breeding sites are more prone to have generalized anti-predator responses to escape predation (Almeida et al 2011). Pereyra et al (2011) found that breeding-site selection is important for the survival of red-belly tadpoles.

A more or less even distribution was observed in all sampling sites. The even distribution of species in all sampling sites can be attributed to geographic or structural location of the marsh and the presence of a number of water structures that were continuous and connected to all sampling sites. This allows easy dispersal of the different species present in the marsh. Moreover, the constant flooding in the area dispersed frogs from one place to another so not a single species dominates.

Socio-economically important amphibians in the marsh. The three edible species of amphibians shown in Figure 8 are socio-economically important species in Agusan marsh for food and bait. *F. cancrivora* was introduced in the marsh by migrants while *O. laevis and F. limnocharis* are native in the area. The presence of exotic species is a threat to native ones but useful to humans since aside from being used as food and bait, it plays an important role in decreasing mosquito population. An absence of frogs in an ecosystem may boost the presence of agricultural pests and mosquitoes (Abdulali 1985; Oza 1990) given their important role as predators. Furthermore, tadpoles are able to consume bacteria and algae, thereby acting as antagonists to the eutrophication of water bodies (Mohneke 2011).

Figure 8. The three species of edible anurans eaten by Manobos, the indigenous people in the area.

Threats to the amphibians in Agusan Marsh. Based on key informant interviews, the two species, *Limnonectes magnus* and *Megophrys* species (Horned Frog) used to be abundantly present in the marsh but at present the local people can no longer catch *L. magnus* and see no more of the Horned frog which is considered sacred for them. Roads constructed near the protected area are seen as one of the causes. Human alteration of habitat, in particular the hydrology of freshwater sites and through building of roads, favors invasive species across landscape (D'Amore et al 2010). In Eastern New Brunswick, Canada, the abundance of the green frog (*Lithobates clamitans*) decreased with increasing traffic intensity (Gravel et al 2012). Roads could act as a source of mortality among amphibians because it acts as strong barriers hampering the migration movements of some species (Sillero 2008).

The low abundance of the Mindano endemic*, L. parvus, Oreophryne sp. 1, Oreophryne sp. 2, Philautus sp.* and the rare species *P. poecilus and R. bimaculatus* suggests that these species are highly threatened due to some of the activities in Agusan Marsh. These species are not very active, their size is attractive to predators and most of them are arboreal.

The introduction of exotic and invasive species into the marsh as food for migrant people from the provinces of Negros, Ilo-ilo, Surigao and Davao posed as a major threat to the endemic species in the area. The species *F. cancrivora, F. limnocharis* and *O. laevis* are species sold for food and as bait for fish in the marsh. These are invasive species with high reproductive ability and are well known generalist feeders (Inger & Stuebing 1989), competing with the endemic species for food and space. In Baja

California Sur, Mexico the invasion of American bullfrog (*Lithobates catesbianus*) results to the increase in the number of wetlands (50%) invaded in only eight years. The populations of rare and endemic species in almost all wetlands are threatened by the arrival of bullfrog (Luja & Estrella 2010). Live specimens are not only potential vectors of pathogens, but may escape, establish feral colonies, and subsequently introduce pathogens to native wild frog populations (Fisher & Garner 2007).

Draining of water of a portion of the marsh by small-scale settlers and absentee developers in the marginal areas in the marsh for conversion to rice fields, fruit orchards and most recently palm oil plantations creates another threat to frogs. The presence of agricultural chemicals is a threat to the frog species in Agusan marsh since rice plantations abound around the protected area. Gurushankara et al (2009) reported that there is decreased growth and development of *Limnonectes limnocharis* tadpoles in Western Ghats, India with an increase of Malathion concentration revealing threats to frog species.

Agriculture can increase sedimentation and decrease hydroperiod in wetlands which can reduce the developmental time of larvae (Lau et al 1997). Habitat fragmentation endangered breeding habitat of green-bellied toad (*Bambina variegata*) because such pools will experience high risks of drying up and flooding resulting to high mortality rate (Cayuela et al 2011). These activities reduce the water holding capacity of the marshland affecting most especially amphibians whose habitat requires abundant water. The agricultural chemicals and pesticides affect the motility and survival of larvae (Turner et al 1989). Agricultural cultivation may negatively influence the post metamorphic body size of amphibians (Gray & Smith 2004). The eastern spadefoot toad (*Pelobates syriacus*) tadpoles speed up their metamorphosis due to water level decrease rate resulting to smaller body size (Szekely et al 2010).

The frequent harvesting of frogs for food and selling of these frogs by the hundreds for bait is common in Agusan marsh. In some cultures notably Asian, Greek and Roman, frog meat has been considered a delicacy for centuries and only a decade ago, almost 95% of the world's demand for frogs' legs was supplied by wild-caught specimens (Teixeira et al 2001). However, recently, consumption of frogs and frog products has increased to levels that are not sustainable. The combination of increasing human population, rising purchasing power, and expanding destruction and degradation of suitable habitat has had fatal consequences for many frog populations in the marsh.

The construction of dams for irrigation, agriculture and forestry since 1970s is a threat since it alters the habitats of most amphibians and other fauna which causes decline in amphibian species. The widespread mining in Mount Diwalwal and Mt. Diwata discharges tons of mine tailings into the Agusan River which lead to mercury pollution (Primavera & Tumanda 2007). Appleton et al (2006), reported high mercury levels in rice crops irrigated with river water in Navoc River area, Mindanao, Philippines. Roa (2007) reported high mercury content of plants and fishes from the lakes and rivers in Agusan marsh. Pefaur & Rivero (2000) noted that with the rapid destruction and contamination of the natural environments some species are placed at extinction risk.

The small-scale and large-scale logging and cutting of trees for human settlements that slowly penetrate into the interior of the marsh reduce the microhabitats of frogs and their tadpoles particularly arboreal species. The changes in landscape have a severe impact on the distribution and population of amphibians by physically altering aquatic and terrestrial environments (Wilbur 1980). The study of Hamer & Mahony (2010) revealed that habitat loss and habitat isolation have contributed to the declines in the green and golden bell frog (*Litoria auria*).

With the ongoing disturbances in the Agusan Marsh, it appears that the endemic species are more at risk. Poynton et al (2007) reported that the uniqueness of the species combined with their evident vulnerability to disturbance make them a subject for particular conservation. The Namibian region has an array of wetland habitats and the absence of caecilians. Over-exploitation of their wetland resources and flow regulation are the major threats but new environmental legislation is being formatted based on the goal of sustainable use (Curtis et al 1997). In Mexico which has the 5^{th} largest amphibian fauna (372 species), about 58% of the species are considered threatened due to alien species, over-exploitation and land use change because of the lack of quantitative studies that support the current conservation status (Alvarez et al 2010).

In Agusan marsh, frog harvesting without limit and selling frogs by the hundreds for bait and per kilo (dressed frog) for food or human consumption is not given much attention. Wildlife laws are in place but implementation is weak.

Conclusions. The presence of endemic species which includes four Mindanao endemic and the presence of four vulnerable species of amphibians in the marsh make it a key conservation site. Despite its protected status, unregulated frog harvesting is rampant. The introduction of non endemic species for food and bait may pose as a big threat to the endemic amphibian population in the marsh if the growth and spread of this introduced species is not regulated. The high diversity of amphibians indicates that the marsh remains a suitable habitat of amphibians. However, the presence of invasive species suggests that the marsh is already disturbed. The invasive species needs to be eradicated or controlled to conserve the endemic amphibian fauna in the marsh. Extensive surveys in the marsh could yield a higher number of species. In view of the alarming rate of habitat loss, rampant gold mining activity in the upland and increasing human encroachment, measures for more effective protection of Agusan Marsh are recommended.

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