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Impact of anthropogenic disturbance on Anurans habitat and species richness in Silago, Southern Leyte, Philippines

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Abstract

Studying the response of anurans to anthropogenic disturbance can be very useful in determining the potentiality of this species as bio-indicator. The study was conducted to assess and describe the habitat condition (i.e., microclimatic, microhabitat, and vegetation structures) and species richness of anurans as affected by the degree of disturbance due to anthropogenic activities in Silago, Southern Leyte, Philippines. Four (10 x 10m) quadrats were established in each site using opportunistic approach in the collection of anurans within the plots per site. Likewise, measurement on the factors associated with habitat condition such as microclimate, habitat, and vegetation structure were undertaken. The collection was done both in daytime and nighttime. The results showed that microclimate, habitat, and vegetation structure differed significantly ($p \leq 0.01$) in each site. This implies that the three sites had different degrees of disturbance that altered the habitat condition of anurans. Moreover, anuran species richness significantly differed ($p \leq 0.05$) in primary forest and slash and burn cultivation but there was no significant difference between secondary and primary forest. Therefore, the results of this study may indicate that the degree of anthropogenic disturbance considerably ($p \leq 0.01$) alters anuran's habitat conditions which significantly ($p \leq 0.05$) affect its species richness.

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Introduction

Anurans or frogs are tailless amphibians whose life cycles include aquatic and terrestrial phases. Early in their development post-hatching, tadpoles survive by eating muck or small aquatic insects, until they finally metamorphose, and only then do they come onto land (Heying, 2004). They are highly sensitive and vulnerable to environmental changes and changes to habitat quality and are extremely sensitive to small changes in temperature and moisture because of their permeable skin and unshelled eggs (Cushman, 2006). Breeding is influenced by rainfall, humidity and temperature, and so any change or alteration in these abiotic factors leads to disruption of lifecycle. This is one reason why anurans, like other amphibians, are directly affected by any environmental stress in their terrestrial or aquatic habitats. In fact, studies have shown that most anurans located in polluted aquatic ecosystem exhibit malformation of organs and other body parts (Dey, 2010).

The combinations of natural and anthropogenic factors such as climate, geographic ranges and vegetation types (Cueto and Casenave, 1999) are also considered to have a significant influence on species distributions and diversity (Mallari, 2009). The pattern of increase in habitat heterogeneity on the structure and composition of vegetation becomes complex if the niche diversity and species diversity increases (Cramer and Willig, 2002; Tews *et al.*, 2004; Gingold *et al.*, 2010; MacClain and Barry, 2010). Moreover, several species of forest anurans are correlated with the quantity and quality of woody debris, litter depth, and over-storey canopy closure (deMaynadier and Hunter, 1995).

The Philippines is one of the few countries in the world that is covered by rain forest (Schulte, 2002). It is also considered as one of the world's mega diverse countries that hosts a large share of endemic flora and fauna (Myer *et al.*, 2000). However, due to the conversion of forests to marginal agriculture, commercial agriculture, and timber plantations, these forest resources are disappearing at an alarming rate (Margraf and Milan, 2004.). Filipino farmers who are poor and lack employment opportunities in the lowland migrate to the upland areas where they cut down secondary forest and practice kaingin farming (Kummer, 1992).

Silago forest is one of the remaining primary forests in the region. However due to rampant and uncontrolled hunting of wildlife and habitat destruction caused by slash-and-burn cultivation or kaingin contributed by residents both within and outside the communities, threat on biodiversity increases (Ceniza *et al.*, 2011). In Barangays Imelda, Katipunan and Catmon, slash-and-burn cultivation is being practiced by the residents. This is their major source of livelihood because many of them do not own land in the alienable and disposable areas.

Thus, the current study examines the impact of ecological disturbance to habitat condition (i.e. rainfall, temperature, relative humidity, vegetation structure, litter depth, and woody debris) and anurans species and population due to anthropogenic activity.

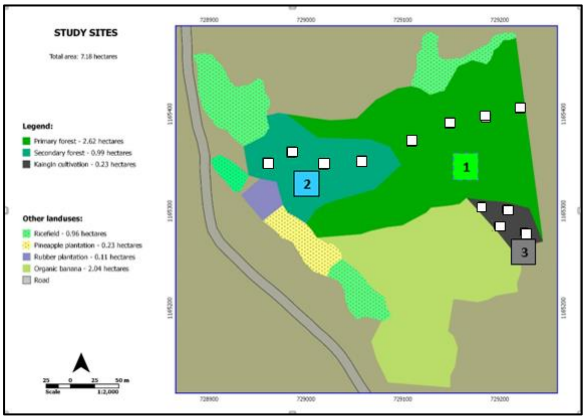
Materials and methods

Selection of Study Sites

The study was conducted in Brgy. Katipunan, Silago Southern Leyte. The study site is part of the Mt. Nacolod Mountain Range and the last remaining primary forest on Leyte Island. The criteria in selecting the site is the degree of ecological disturbance following the rate of disturbance by Miller (1982). Hence, the following sites were selected: primary forest, secondary forest, and slash and burn cultivation (Fig 1).

Sampling Method

Fig. 1 presents the four (10 x 10m) quadrats that were randomly established in each site following the methods of Williams (2004). Anurans were collected at early morning 6:00 - 9:00 am and evening at 7:00-10 pm (Warguez *et al.*, 2013). The Visual Encounter Survey was used to search high potential areas throughout the sampling sites. These are on the surface and under rocks, logs, trees, and other debris within each established plot.



Note: (Site 1- Primary forest; Site 2- Secondary forest and Site 3- slash and burn cultivation)

Fig. 1. Location of the sampling plots that were randomly established within the three selected study sites in Brgy. Katipunan, Silago, Southern Leyte

Measurement of Anurans Morphometric

The following morphometric measurements were taken using a vernier caliper to the nearest centimeter to support identification of anurans to the species level following Alcala and Brown (1998) and Alcala (1996) as adopted by HARIBON Foundation guidelines for amphibians. Morphometric includes Snout-Vent Length (SVL), a measurement from the snout to the tip of the ventral part; Tibia Length (TBL), from the tibia to the tip of the phalanges (leg not straightened); Head Length (HdL), from the snout to the tympanum; Hind limb Length (HbL), entire length of the hind limb (straightened); Eye Diameter (ED), diameter of the entire eye; Tympanum Distance (TD), distance of tympanum from both ends; Snout Length (SL), from the snout to the eye; and Head Breadth, from one shoulder to the other.

Identification of Anurans

The morphometric of each captured frog were measured. This was done in order to support the identification of anurans. Likewise, photographs of each captured anurans were taken using a digital camera. Pre-identification was done using the field guide of Diesmos and Alcala (2011). Moreover, photos and morphometric measurements were sent to an expert to confirm preliminary identification. Lastly, final confirmation was done using IUCN List of Threatened Species available at (http://www. iucnredlist.org/amphibians, 2015).

Assessment of Vegetation Structure

Trees and other associated plants inside the plot were counted based on the following vegetation strata: a.) Dominant, b.) understorey vegetation, c.) ground cover. Dominant stratum are the vegetation present in the uppermost stratum within a plot. Trees with diameter at breast height >15cm and height >20m were categorized as dominant tree. Understorey vegetation is the stratum next to the dominant layer which usually consists of shrubs and bushes. Trees with diameter at breast height <15cm and height <20 m were categorized under undersotrey layer. The herbaceous layer is the vegetation present in the ground covering the soil such as grasses and ferns. Taxonomic identification of trees, associated ferns, grass, palms, and rattan was done at genus level.

Determination of Microhabitat Structure

Quantity and quality of Coarse Woody Debris (CWD) were determined by counting all CWD with small-end diameter (< 10cm) and greater than or equal to 10cm that fell inside the quadrat. Each piece was rated on its degree of decomposition (Woodwall and Willams, 2005) ranging from 1 (sound, intact, no rot) to 5 (no structural integrity, soft, powdery). Also, litter depth in each quadrat was measured using a meter stick by randomly selecting three points of location per quadrat.

Measurement of Microclimatic Factors

Microclimatic factors measured were air temperature, relative humidity, and rainfall. Air temperature was taken at each quadrat per study site using a thermometer in an interval of 3 hours starting from 7:00 am to 4:00 pm. Relative humidity and rainfall were measured using a sling psychrometer and improvised rain gauge, respectively (with the same collection time and interval with the air temperature measurement).

Calculation of Species Richness

Calculations of species richness was done per plot and study site using the formula (Magurran, 1988):

Species Richness (S)

S = Total number of species Equation 1

Statistical Analysis

All data were tested for normality and heterogeneity using PROC Univariate of Statistical Analysis System version 9.1 (SAS, 2003). PROC GLM (general linear model) procedure was initially performed to check for effects of ecological disturbance on microclimatic factors (i.e., temperature, relative humidity, and rainfall), habitat structure (i.e., litter depth and quantity and quality of coarse woody debris), vegetation structure (i.e., herbaceous layer, understorey, and climax strata), and species richness of anurans. The final models for each response variables were analyzed including but those with only significant main factors effect for anurans. Duncan multiple range test (DMRT) and Least square differences (LSD) were carried out to compare means of independent variables with significant variations at $p \leq 0.05$

Results and discussion

Anurans Species Richness

The species richness in the primary forest is significantly ($p \leq 0.05$) different from slash-and-burn cultivation (Fig. 2). Frog population increases steadily during natural succession, attaining similar characteristics to those from mature forest after regeneration following slash-and-burn cultivation (Pawar *et al*., 2004). Meanwhile, when the habitat starts to stabilize its condition (that is conducive to anurans), the frog species starts to increase dramatically.

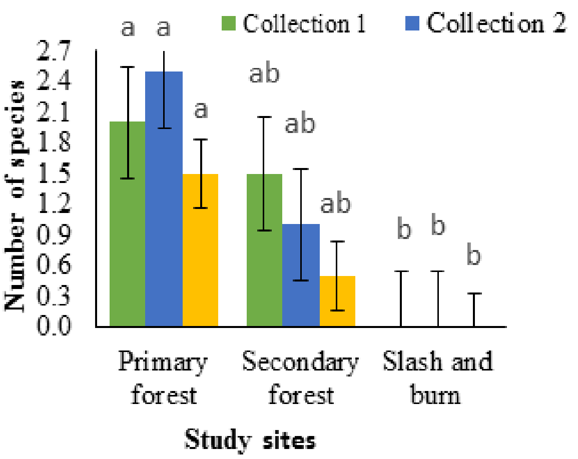


Fig. 2. Number of species of anurans observed in the different sites per collection period

Meanwhile, the total number of species in the primary forest, secondary forest, and slash-and-burn cultivation were S=7, S=4, and S=0, respectively. The result is consistent with the study of Mallari *et al.* (2013) in Silago forest where they observed a maximum number of anurans species of S=4. Mallari *et al.* (2013) reported that the number of species is correlated to the degree of disturbance. Furthermore, the density of frogs observed was eight (8) frogs per 100m² in the primary forest while four (4) frogs per 100m² in the secondary forest and zero (0) frog in the slash-and-burn cultivation. This supports the study of Sluys *et al.* (2007) that the density observed in the rainforest in Brazil is four (4) frogs per 100m². Moreover, it was observed that there were four (4) species of frogs (i.e, *Platymantis corrugatus, Occidozyga laevis, Platymantis sp.,* and *Staurois sp*) found in primary forest that were not observed in the secondary forest and slash-and-burn cultivation while *Hylarana erythaea* (an introduced and invasive species) was observed in the secondary forest and was not observed in the other two sites.

Habitat Conditions that Influence Anurans Species Richness

Three environmental factors were considered in this study to determine the habitat condition of each site that influenced anurans species richness. These are microclimatic factors including temperature, relative humidity and rainfall (Cueto and Casenave 1999; Cushman, 2006), microhabitat structure including litter depth and quantity and quality of coarse woody debris (deMaynadier and Hunter, 1995), and vegetation structure with the following layers, herbaceous layer, understorey and climax or emergent (Cramer and Willig 2002; Tews *et al.*, 2004; Gingold *et al.*, 2010; MacClain and Barry 2010).

Microclimatic Factors

In this study, three atmospheric factors (i.e., temperature, relative humidity, and precipitation) were measured that considerably affected the diversity of anurans in each study site.

The results showed that temperature (during second and third collection) were significantly ($p \le 0.01$) different in the three sites (Table 1). This is probably because the temperature in the primary and secondary forest sites is constantly stabilized by its multi-strata vegetation structure (Table 3). The result agrees with the findings of Markussen, (2005) where temperature in secondary forest is 2°C higher compared to primary forest. Hence, the result of this study supports the findings of Bickford, (2005) that anurans tend to seek cooler microhabitat with lower temperature. However, during the first collection, secondary forest and slash-and-burn cultivation had no significant difference. This is because during the measurement the sun was covered with clouds which prevented the radiation from penetrating to the land surface thereby stabilizing the temperature in both sites.

Table 1. Microclimatic factors measured at the different study sites per collection period.

Climatic factors	Primary forest	Secondary forest	Slash and burn cultivation
1. Temperature (^{0}C)			
Sampling 1	29.85±0.11^a	30.09±0.11^b	31.71±0.11^b
Sampling 2	25.27±0.03^a	25.87±0.03^b	27.17±0.03^c
Sampling 3	24.63±0.04^a	24.86±0.04^b	26.15±0.04^c
2. Relative Humidity (%)			
Sampling 1	83.74±0.71^a	80.69±0.71^b	67.81±0.71^c
Sampling 2	96.52±0.41^a	96.05±0.41^b	93.33±0.41^c
Sampling 3	96.09±0.16^a	95.52±0.16^b	93.84±0.16^c
3. Rainfall (cm week^{-1})			
Sampling 1	0.18±0.02^a	0.24±0.02^b	0.38±0.02^c
Sampling 2	0.89±0.01^a	0.92±0.01^b	1.23±0.01^b
Sampling 3	0.38±0.01^a	0.53±0.01^b	0.72±0.01^c

Note: least square means in each row with different letter superscript (a-c) are significantly different at $p<0.05$

The results for relative humidity showed that all sites were significantly ($p \le .0.01$) different (Table 1). Reason might be due to vegetation structure which is obviously different in all study plots. Moreover, secondary forest has no dominant layer which might affect the retention of water vapor in the area. According to Bernatzky (1978), the stomata present in the leaves prevents the radiation to penetrate by absorbing and converting the heat energy into oxygen and glucose, thereby, minimizing the intensity of radiation which evaporates the water vapor rapidly resulting to higher relative humidity and lower temperature.

On the other hand, the rainfall during the collection period were significantly ($p \le 0.01$) different in the three sites (Table 1). According to Chazdon (2003), mean annual rainfall differs between primary and secondary forest. The high multi strata vegetation cover in the primary forest can trap more rain drops compared to vegetation layer with less strata in the secondary forest (Table 3). However, in the case of second collection, there was no significant difference between secondary forest and slash and burn. This could probably be due to the microclimate condition where some areas experience rain while some parts have none which is usually observed in tropical evergreen rainforest like in the study site. Also, the throughfall or stem flow of the rain (which were not determine in the study) might contribute to the results.

Microhabitat Structure

The results showed that litter depth was significantly different ($p \le 0.01$) in each site (Table 2). Hence, the result implies that litter depth affects anurans richness (Fig. 2). Several species of forest anurans are correlated with the quantity and quality of woody debris, litter depth, and over-storey canopy closure (deMaynadier and Hunter, 1995). According to Fauth *et al.* (1989), litter depth may enhance diversity by providing a wider range of microhabitats and refuges against predators, as well as greater densities of arthropod preys. Moreover, for terrestrial breeding frogs, the leaf layer may provide adequate conditions for egg laying. This may facilitate the coexistence of more individuals and more species in the leaf litter (Sluys *et al.*, 2007).

Table 2. Microhabitat structure measured at the different study sites.

Microhabitat structure	Primary forest	Secondary forest	Slash and burn cultivation
Litter Depth (cm)	6.04±0.52^a	1.87±0.52^b	0.00±0.52^c
Quantity CWD	2.25±1.25^a	0.75±1.25^a	7.25±1.25^b
Quality CWD	2.75±0.56^a	1.63±0.56^b	1.00±0.56^c

Note: least square means in each row with different letter superscript (a-c) are significantly different at $p<0.05$

Table 2 also shows that primary and secondary forest were significantly ($p \leq 0.01$) different with slash-and-burn cultivation in terms of the quantity of coarse woody debris. However, the high number of CWD in the slash-and-burn cultivation was due to the conversion of forest to agriculture where cutting and burning of trees were usually undertaken. Hence, the site was dominated by tree stumps and partially burned logs. The result of quality of CWD showed significant ($p \leq 0.01$) difference in all sites with highest observed value in the primary forest. This could probably because primary forest has higher decomposition rate. Therefore, the higher the quality of CWD, the greater the probability that anurans use this as their habitat (Woodwall and Willams, 2005) which is supported by the data in Fig. 2.

Vegetation Structure

Table 3 shows a significant difference ($p \leq 0.01$) in the understorey layer for all site. The high number of understorey in the secondary forest was because it is on its early successional stage where most small pioneer trees and shrubs dominates the understorey layer. Likewise, herbaceous layer had significant difference ($p \leq 0.01$) in all sites. The high number of herbaceous layer observed in the secondary forest was due to the community of grass and some ferns dominating the site while in the primary forest was because of wildlings from the trees.

Table 3. Vegetation structure measured at the different study sites.

Vegetation strata	Primary forest	Secondary forest	Slash and burn cultivation
Emergent	4.25 ± 8.54^a	0.00 ± 8.54^b	0.00 ± 8.54^b
Understorey	12.50 ± 1.67^a	19.25 ± 1.67^b	0.00 ± 1.67^c
Herbaceous Layer	50.00 ± 0.28^a	106.50 ± 0.28^b	0.00 ± 0.28^c

Note: least square means in each row with different letter superscript (a-c) are significantly different at $p<0.05$

According to Feder (1983), anuran species maintain close contact with forest floor substrates and habitat selection are also affected by any anthropogenic activities. The pattern of increase in habitat heterogeneity on the structure and composition of vegetation becomes complex if the niche diversity and species diversity increases (Cramer and Willig, 2002; Tews *et al.*, 2004; Gingold *et al.*, 2010; McClain and Barry, 2010). This implies that clearing the vegetation would disturb the area; thus, greatly affecting the habitat condition and eventually the species richness of the frogs.

Conclusion

The results of the study affirm that anthropogenic disturbance alters anurans habitat condition, thereby, affecting its species richness and population. The study was not able to find specific species of anurans that will be used as indicator to ecological disturbance. However, it is worth mentioning that there was a considerable reduction ($p \leq 0.05$) of anurans species in the primary forest, secondary forest, and slash-and-burn cultivation with values of seven (7), four (4) and zero (0) respectively. Moreover, the study suggests that microclimatic parameters, microhabitat, and vegetation structures appear to be the factors influencing habitat condition of anurans which significantly ($p \leq 0.05$) affect anurans species richness.

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