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Structure and Composition of Reptile Communities in Human Modified Landscape in Gianyar Regency, Bali

Ida Ayu Ari Janiawati,[1] Mirza Dikari Kusrini,[2*] Ani Mardiastuti[2]

[1] Department of Forest Resources Conservation and Ecotourism, Tropical Biodiversity Conservation Program, Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia.

[2] Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry, Bogor Agricultural University, Bogor, Indonesia.

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ABSTRACT

As one of the centres of tourism in Bali, Gianyar Regency has undergone a rapid development rate which could threaten wildlife, including reptile community. This research was carried out in July to October 2014 to (1) analyse the reptile community on various gradients of human modified landscape, (2) determine the relationship between environmental character and reptiles, and (3) determine body size trend of generalist species along landscape gradient. Standard visual encountered surveys were used to observe reptile community in four human modified landscape (settlements, rice fields, farmland/cropland, and monoculture stands). We found 21 species of reptiles ($n = 602$ individuals) and the Shannon–Wiener index for diversity was 1.78. Reptile abundance tends to decline in increasing level of modification. Water sources and vegetation cover were positively correlated to reptile community, while disturbance factors (i.e. decrease in area size and shorter distance to settlements) give negative impact to reptile community. There was no correlation between body size of generalist species of reptile (*Gekko gecko*) and level of landscape modification.

1. Introduction

The existence of human modified landscape is as old as the human existence in the earth. Although the number of wildlife in this landscape might not be as diverse as natural area, human modified landscape plays an important role in the existence of wildlife. Indeed, for some species living in human modified landscape is better than living in the natural area (Liu & Taylor 2004) and they will thrive in this area (Trimble & van Aarde 2004). However, human modified landscape varied according to the degree of human disturbance, for instance city landscapes are more disturbed than farms and traditional villages.

Some areas in Indonesia have changed into human modified landscape such as monoculture stands, farmland/cropland, rice fields, and settlements. In Gianyar Regency, Bali Province, human modified landscapes are mostly caused by high activity in tourism sectors (BPS 2012). Forest and rice fields slowly become scarce and changed into tourist accommodations, restaurants and other related tourism attractions. However, no special attention was given to the impact of that change for wildlife conservation, especially reptiles.

Each type of human modified landscapes has different environment character (habitat and disturbance); therefore, the structure and composition of the reptile community in each formation will be different. Reptile communities that inhabit specific habitat will give different responses to landscape change. For example, conversion of natural forests to plantations will decrease reptile population (Kanowski *et al.* 2006). Research by Andrews *et al.* (2008) showed that the existence of highway may lead to a decrease of abundance and richness of reptile. Highway/road access is one of many consequences of landscape change caused by the existence of human modified landscapes.

In the last decade, declining reptile population has been reported due to habitat degradation, habitat change, and habitat loss (Hokit & Branch 2003; Todd *et al.* 2010). Most reptiles have the highest position in food tropics (Todd *et al.* 2010), thus it has important roles in the ecosystems as predators. Like other predators, the reptile will decrease its body size along with higher habitat disturbance (Gul *et al.* 2014). This research aimed to (1) analyse reptile community in a gradient of modified landscape, (2) analyse the correlation of habitat characters and reptile communities on modified landscape, and (3) analyse body size trend of generalist species in modified landscapes.

* Corresponding author.
E-mail address: kusrini.mirza@gmail.com (M.D. Kusrini).
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2. Methods

The study area was located in five of the seven sub-districts of Gianyar: Gianyar, Blahbatuh, Sukawati, Ubud and Tampaksiring. Locations were selected based on elevation, mostly lowlands area (0–800 m above sea level; Figure 1). We selected four types of land use in modified landscape based on level of disturbance. The land use system consisted of monoculture tree stands of *Paraserianthes falcataria* cropland/farmland dominated by annual or semi-annual crops, rice fields with continuous watering *subak* system and traditional Balinese settlements and their gardens.

Samplings were carried out during dry season from July to October 2014. Ten observation points for each land use were selected using stratified random sampling. Surveys were carried out in the morning (6:00 – 8:00 AM) and evening (7:00 – 9:00 PM) for 3 consecutive days for each point. Reptiles were observed using the standard Visual Encountered Surveys (VES) method with 2 hours' time constrained (Doan 2003) by three observers. For every captured reptiles, we recorded coordinates, date and duration of survey, activity, substrates, species name and other supporting information. Identification of reptile was carried out using Das (2010) and McKay (2006). Every individual was measured to obtain data on the body length from snout to the cloaca (snout vent length [SVL]) and the overall length (total length [TL]) using calliper (0.05 mm accuracy), and then body mass using digital scale body weight (0.1 g accuracy) and 10 N spring balance. No specimens were taken, all individuals were released after identification and measured in the same area where they were caught.

Encounter frequency was recorded as individuals per time unit. The encounter frequencies were arbitrarily categorized into frequent (0.04–1.17 individual/min), common (0.02–0.04 individual/min), and rare (0–0.01 individual/min). All individuals were captured (except for the monitor lizard which accidentally escaped) and identified to the species level using Das (2010) and McKay (2006).

Environment characters in term of vegetation cover, presence of water, and degree of disturbance were observed. Canopy closure and undergrowth covers (including woody shrubs, bushes and grasses) were measured for vegetation cover using line intercept techniques (Whitman & Siggeirsson 1954). In each land use system, we selected a 20 × 20 m plot and made 10 transects of 2 m apart. Distance of each individual reptile found to the nearest water source was also recorded. The degree of disturbance was measured as the possible nuisance from human activities surrounding the amphibian habitat. It was measured by the distance of each observation point to the nearest settlement or roads using a geographic information system–based map. All distance coordinates were taken using Garmin Etrex 30. Pre-survey indicated that *Gekko gecko* was abundant and widely distributed. This species was selected for further study on trend of body weight along modified landscape gradient. The SVL and TL of *G. gecko* were measured using a calliper to the nearest 0.05 mm, and then weighed using digital scale to the nearest 0.1 g. All captured individuals were released on site after measurements.

Shannon-Wiener diversity indices (Heip & Engels 1974) were calculated for each type of land use. Differences of species richness among the modified landscapes were examined using Kruskal-Wallis test (Colomba & Liang 2011). The reptile community similarities for each land use type were assessed using single linkage method of Euclidean Distance (Bingham *et al.* 2010) and the dendrogram was drawn using MINITAB 16. To explain the correlation of each environmental character measured to reptile community parameters (abundance, species richness, and species diversity), we used Spearman rank correlation coefficient with an accuracy level of 95% ($p \leq 0.05$) and 99% ($p \leq 0.01$). We conducted similar analysis to see the correlation between disturbance factors to reptile communities.

To assess body condition of *G. gecko,* we used a body mass index (i.e. ratio of the body weight to body length). We used the result to determine the correlation of landscape modification level to body condition of generalist species using Spearman rank correlation coefficient with an accuracy level of 95% and 99%.

3. Results

3.1. Reptile communities in different land use of modified landscapes

We found 23 species of reptiles ($n = 602$ individuals) in four different land uses, consisted of three families of snakes (Colubridae, Natricidae, Phytonidae) and four families of lizards and skink (Agamidae, Gekkonidae, Scincidae, and Varanidae). Lizards were exceedingly abundant and diverse (561 individuals; 13 species) compared to snakes (41 individuals; 10 species) (Table 1).

The highest number of snakes and lizards combination was found in monoculture stands ($n = 259$), followed by farmland/cropland ($n = 173$), rice fields ($n = 119$) and settlements ($n = 51$). In general, the individual abundance and species richness tend to decrease along the higher landscape modification. The trend, however, is different for diversity indices. The highest to the lowest indices were settlements (H' = 1.76), monoculture stands (H' = 1.72), cropland/farmland (H' = 1.51), and rice fields (H' = 0.77). Statistical tests revealed that there were significant differences in abundance ($p < 0.05$; df = 3), and species richness ($p < 0.05$; df = 3) among human modified landscapes. Abundance (mean rank = 34.15) and species richness (mean rank = 31.65) of monoculture stands differed from the other land use types, although settlements showed a slightly higher H' value.

The analysis of the community composition and dendrogram based on abundance and species presence (Figure 2) showed that there were two distinct reptile communities (similarity only about 50%) in the research area: reptiles in settlement areas and reptiles in other three land uses. In the three land uses (monoculture stands, cropland/farmland and rice fields), community similarities were very high (>95%).

3.2. Environmental characters and reptile communities

Habitat characters for each land use types were significantly different among all land use (canopy closure: $p < 0.05$, df = 3; undergrowth cover $p < 0.05$, df = 3; water presence: $p < 0.05$, df = 3). As predicted, the increase of canopy closure percentage significantly increased abundance ($r_s = 0.636$; $p < 0.01$), species richness ($r_s = 0.337$; $p < 0.05$), and species diversity ($r_s = 0.774$; $p < 0.01$). Meanwhile, increase of undergrowth cover could only increase abundance ($r_s = 0.359$; $p < 0.05$) and species richness ($r_s = 0.686$; $p < 0.01$), but not species diversity. As for the water presence, increasing distance from water source significantly reduced the species richness ($r_s = -0.344$; $p < 0.05$).

Distance from the roads as a disturbance predictor did not have significant correlation with the reptile community. Area size had significant and positive correlation to abundance ($r_s = 0.617$; $p < 0.01$), species richness ($r_s = 0.759$; $p < 0.01$), and species diversity ($r_s = 0.367$; $p < 0.01$). Similarly, abundance ($r_s = 0.540$; $p < 0.01$), species richness ($r_s = 0.683$; $p < 0.01$), and species diversity ($r_s = 0.472$; $p < 0.01$) would increase with distance from settlements.

3.3. Body size of *G. gecko* along landscape gradients

G. gecko was found in all land use types ($n = 56$; average 0.03–0.24 individual/min; see Table 2) and was considered as a

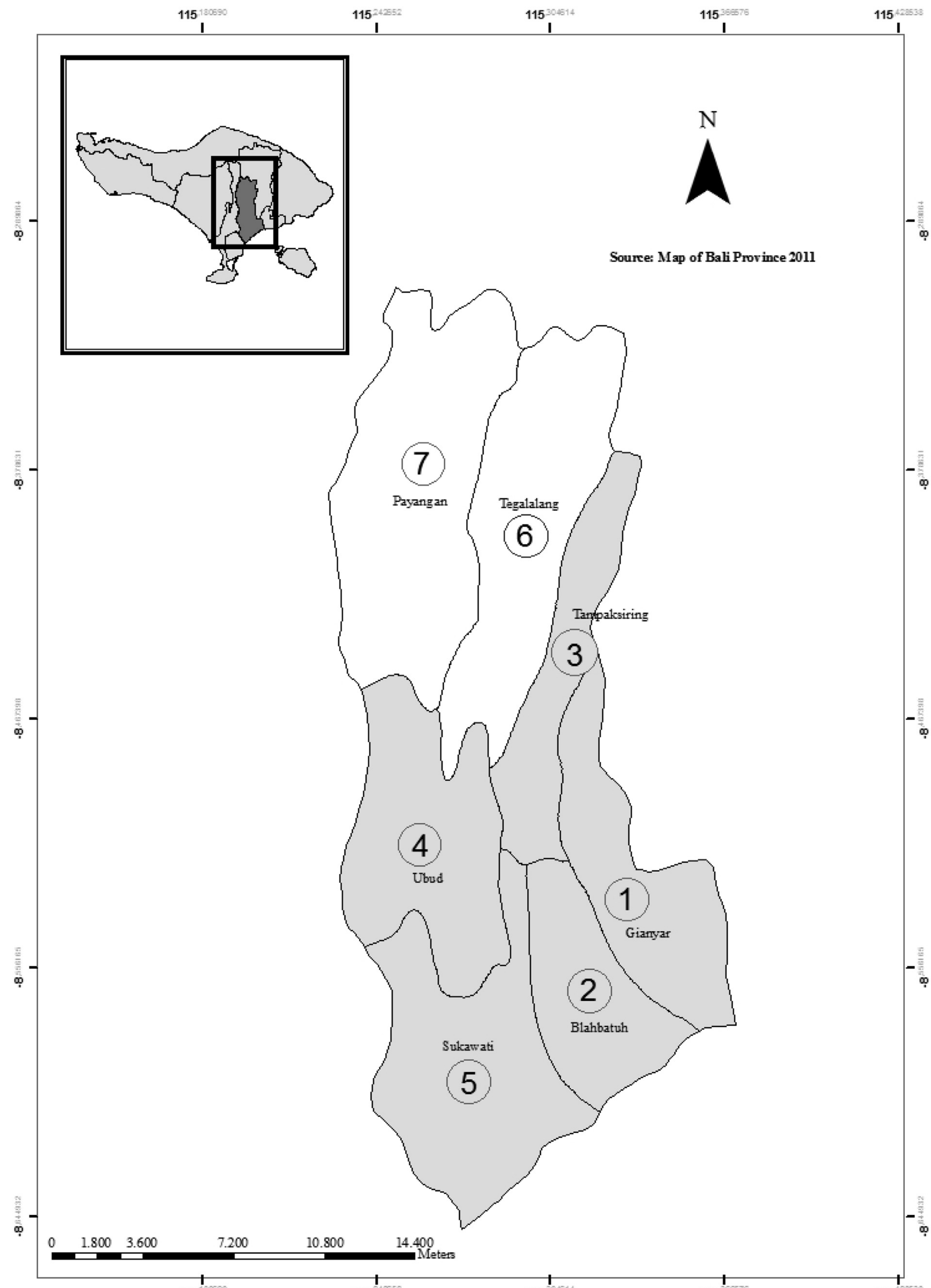

Figure 1. Research location in Bali Island, Indonesia.

Table 1. Composition of reptile communities in different gradients of human modified landscape

Level of modification	Land use type	Snakes		Lizards	
		Number of individuals	Number of species	Number of individuals	Number of species
High	Settlements	1	1	50	7
↕	Rice fields	10	4	109	3
	Farmland/ cropland	8	3	165	9
Low	Monoculture stands	22	6	237	10

generalist, although its abundance did not increase with the level of landscape modifications. *G. gecko* was the only reptile species found in all land use types.

Weight, SVL, and body mass index of *G. gecko* tended to differ among the four land use types we studied. In the cropland/farmland the species appeared to have a bigger mass, whereas in the settlements they had a tendency of longer body (Table 3). However, statistical tests showed that there was no significant difference of SVL ($p = 0.355$, df = 3), TL ($p = 0.319$, df = 3), weight ($p = 0.613$, df = 3), or body mass index ($p = 0.804$, df = 3) among the four land use types, probably due to the high standard deviation and small sample sizes. Furthermore, there was also no significant correlation between level of landscape modification to SVL ($r_s = -0.096$; $p > 0.05$), TL ($r_s = 0.118$; $p > 0.05$), weight ($r_s = -0.055$; $p > 0.05$), and body mass index ($r_s = -0.085$; $p > 0.05$).

4. Discussion

4.1. Reptile communities on different levels of landscape modification

Number of reptiles found in this research represented 35.93% of all reptiles in Bali. In general, there was a decline for both abundance and species richness on high modification landscape (settlements). This finding was similar to other studies (see Gibbons *et al.* 2000; Hokit & Branch 2003; Gillespie *et al.* 2005; Kanowski *et al.* 2006; McKinney 2008; Todd *et al.* 2010; Botejue & Wattavidanage 2012), most probably caused by a decrease in area size and habitat change (Gillespie *et al.* 2005). High modified landscapes (i.e. settlements) contain few remnant vegetation (McIntyre & Hobbs 1999), thus only have limited resources. However, based on index of species diversity, settlements had a slightly higher diversity index compared to monoculture stands. Index of diversity measured the proportion of species found and finding opportunities, in essence it is closely related to the evenness and richness. There was no dominant species in settlements, thus abundance of all species was relatively similar, whereas in monoculture stands *Eutropis multifasciata* tend to dominate the community.

Reptile communities differed among monoculture stands, rice fields, and settlements. Settlements had the lowest similarity to other communities because of its different composition. In this area, the dominant family was Gekkonidae, whereas Scincidae family dominated other three land use types. The difference in species/family dominance might be caused by the presence of domestic dogs and cats in the settlement areas. Ground skinks most likely be predated by dogs or cats, and thus tend to avoid settlement areas.

4.2. Relationship between environmental characters and reptile communities

In each type of landscapes, canopy closure, undergrowth cover and distance to water resources were differed. The difference of habitat characters created a different community response and this reflected in reptile communities. Reptiles use vegetation cover to protect themselves from environmental changes or predators (Botejue & Wattavidanage 2012). The finding in our research showed that abundance and species richness increased with higher percentage of canopy closure and undergrowth cover. Vegetation cover is able to control temperature, manage moisture, create a stable microhabitat, and contribute to habitat complexity (Hanson 2012). Canopy cover is also very important as a key factor to assess forest biomass (Baxley & Qualls 2009) because as canopy cover becomes denser, more leaf litter will be produced. Leaf litters are needed by reptiles to maintain a stable body temperature in

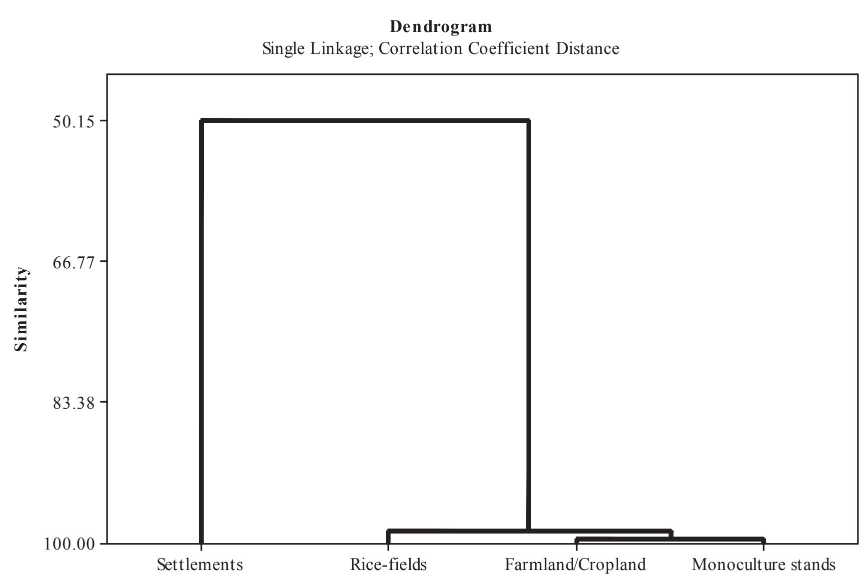

Figure 2. Dendrogram of reptile communities in different gradients of human modified landscape.

Table 2. The relative abundance of reptiles along human modified landscape

Species	Settlements	Rice fields	Cropland/farmland	Monoculture stands
Snakes				
Colubridae				
Ahaetulla prasina	−	+	++	+
Chrysopelea paradise	−	−	++	−
Coelognathus flavolineatus	−	−	++	−
Dendrelaphis pictus	−	−	+++	++
Lycodon capucinus	−	−	++	−
Lycodon subcinctus	−	−	+	−
Ptyas korros	+	−	−	−
Sibynophis geminatus	−	+	+	+
Natricidae				
Rhabdophis chrysargos	−	+++	−	−
Phytonidae				
Broghammerus reticulatus	−	+	−	−
Lizards				
Agamidae				
Broncochela jubata	−	+++	+++	+++
Draco volans	−	−	+++	+++
Gekkonidae				
Cyrtodactylus fumosus	+++	−	+++	+++
Cyrtodactylus marmoratus	+++	−	+++	−
Gehyra mutilate	++	−	−	+
Gekko gecko	++	+++	+++	+++
Hemidactylus frenatus	+++	−	−	+++
Hemidactylus platyurus	+++	−	−	−
Hemiphyllodactylus typus	+	−	−	−
Scincidae (Skink)				
Cryptoblepharus renschi	−	−	+	+
Eutropis multifasciata	−	+++	+++	+++
Lygosoma quadrupes	−	−	+++	−
Varanidae (monitor lizard)				
Varanus salvator	−	−	+	+

+++: frequent (0.04−1.17 individual/min); ++: common (0.02−0.04 individual/min); +: rare (0−0.01 individual/min); −: not found

extreme weather. The existence of leaf litter is also associated with an abundance of insects and small mammals that usually preyed by reptiles (Miller *et al.* 2004).

Todd *et al.* (2010) stated that loss of water resources can be a serious threat for reptiles. This is consistent with the results of the study, which found a negative correlation between the distance of water source and the abundance of reptile species.

Modifications in each landscape showed different character of disturbance. Residential area is closely related to human existence and the level of interference is usually high. According to Gillespie *et al.* (2005) a disturbed area is characterized by the presence of humans, and reptile richness will be lower than less disturbed areas. This study showed that as distance from residential area increased, the abundance, richness, and diversity of reptiles also increased. As habitat becomes closer to residential area, the variation will be lower (McIntyre & Hobbs 1999). A more varied habitat can accommodate more species because more resources can be utilized.

Other disturbance factors, i.e. distance to road, can also cause severe threat to wildlife, especially reptiles (Andrews *et al.* 2008; Fahrig *et al.* 1994) as remaining habitat will be fragmented into isolated patches (Marzluff & Ewing 2001). Study by Glista *et al.* (2008) showed that 20%−80% of vertebrates will be hit or run over in the highway, especially reptiles (Gibbs & Steen 2005; Coleman *et al.* 2008; Langen *et al.* 2009; Mazerolle 2009). Several species of snakes tend to avoid highway (Andrews *et al.* 2008). This study did not showed significant correlation between distances of roads to reptile community. The quality of road in the study area might differ to those reported previously, as roads in Gianyar mostly have low traffic density and relatively quiet. The habitats close to roads might also still be providing the same high quality habitat as those far from road as stated by

Table 3. Average ± SD of body size of *Gekko gecko* along human modified landscape

Level of modification	Land use type	*n*	Body weight (g)	Snout Vent length (cm)	Body mass index
High	Settlements	4	11.48 ± 10.94	86.8 ± 24.10	0.06 ± 0.05
	Rice fields	4	9.97 ± 7.39	70.5 ± 21.00	0.07 ± 0.03
	Cropland/farmland	13	15.63 ± 9.67	69.92 ± 26.12	0.26 ± 0.63
Low	Monoculture stands	29	14.43 ± 10.72	81.21 ± 15.49	0.11 ± 0.09

Loehle *et al.* (2005). In addition, the presence of water sources near roads will improve the quality of habitat to those away from roads.

Habitat size will influence the herpetofauna diversity, especially reptiles (Burbrink *et al.* 1998). This study demonstrated a positive correlation between habitat size and abundance, richness, and diversity of reptiles. Broader landscapes can provide a wider habitat, thus it supports more species (Ricketts 2001).

According to Hibbitts *et al.* (2013) a generalist species is a species that is capable of using a limited element and specific habitat. As a generalist species, the abundance of *G. gecko* tends to decrease in high modifications (disturbed) landscape. This is in contrary to other study Gillespie *et al.* (2005), which mentioned that the abundance of generalist species tends to increase in the disturbed area. The abundance of generalist species will increase due to lack of competitors, therefore there is an increase of space and opportunity to grow (Jonsen & Fahrig 1997).

In residential area we found six species of lizards and geckos, thus competition between species is tighter and individuals of each species, especially *G. gecko* have limited opportunities to utilize the resources. Meanwhile, in low interference landscape (monoculture stands), although the number of reptiles was lower yet the species in this landscape do not utilize the same resources, thus the abundance of *G. gecko* was higher.

The pattern that applies on generalist is usually different to specialist species (Richmond *et al.* 2005; Batary *et al.* 2007; Hibbitts *et al.* 2013). However, the pattern cannot be seen from *Ptyas korros* because of the low number of observation. Only one snake was found in residential landscape, whereas according to Das (2010) this species might also be found in forests or agricultural areas. The low number of this snake did not reflect the low abundance of this species as study was only conducted for several days during dry seasons and the snake tends to hide in the ground.

4.3. Differences of body size of *G. gecko* among different landscape modification

Habitat changes by human disturbance will give different response to each species. Generalist species might respond by changing its size (Battles *et al.* 2013) as a response to differences in prey size in each habitat. Body size of generalist usually decreases with the increasing level of disturbance (Dickinson & Fa 2000; Gul *et al.* 2014). However, we did not find any correlation between the levels of disturbance or modification to body size of *G. Gecko*. We suspected that the amount of prey is similar among each land use and competition is low. Although each land use has different environmental character, the quality and composition of the available habitat for *G. gecko* are relatively similar.

In addition, there might be bias in data analysis due to unequal age class. Body size will increase as species aged and then reach asymptote (Bjorndal *et al.* 2013). In the study, we did not use similar age classes for comparison as analysis was conducted using individuals found during survey. Larger sized *G. gecko* in monoculture stands were more difficult to catch because they are on a high tree trunks, whereas *G. gecko* with the similar size could be captured easily in residential landscape.

Conflict of interest

None.

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