A report on the small mammals in mixed-use urbanized habitats in the southern Central Cordillera, northern Luzon

Aris A. Reginaldo*[,1], Perry S. Ong[†,2], and Lawrence R. Heaney[3]

[1]Department of Biology, College of Science, University of the Philippines Baguio
2600 Baguio City, Philippines
[2]Institute of Biology, College of Science, University of the Philippines Diliman
Diliman, Quezon City 1101, Philippines
[3]Field Museum of Natural History, 1400 S Lake Shore Drive, Chicago, IL 60605, USA

ABSTRACT

The effect of habitat disturbance on small, non-volant mammals in the Philippines is little known. From January to March 2019, we surveyed small mammals in three pine-dominated forest fragments in the southern Central Cordillera to identify the species present and describe habitat use. In each study area, two were in La Trinidad, Benguet Province and one in Baguio City, we trapped in three adjacent areas of disturbed habitats (remnant montane broad-leafed forest patches, pine stands, and agricultural areas). In a total of 10,593 trap nights, we recorded eight species: five native species (*Apomys musculus*, *A. abrae*, *Bullimus luzonicus*, *Chrotomys whiteheadi*, and *Rattus everetti*) and three non-native species (*Suncus murinus*, *R. exulans*, and *R. tanezumi*). Seven of the species (five native species) were recorded in Wangal; six species (three natives) in Puguis; and five species (two natives) in Ambiong. *Apomys abrae* and *S. murinus* used remnant montane forest patches more commonly than the other habitats. Notably, *C. whiteheadi*, *R. everetti,* along with *R. tanezumi*, were often recorded in the agricultural areas. The set of species is quite remarkable in that native species have persisted in heavily disturbed landscapes in that native species persisted. Disturbance facilitates the establishment of non-native pest species, and their presence may aggravate the adverse effects of disturbance on native species, in addition to causing harm to human activities. Improving habitat quality in pine-dominated forest fragments and controlling the pest species may help facilitate the recovery of native mammal populations.

INTRODUCTION

Small non-volant (= non-flying) mammals typically respond to habitat disturbance (e.g., Ong and Rickart 2008; Pardini 2004). However, we are in the early stages of understanding the extent of effects of various forms or levels of disturbance on the many distinctive native mammals in the Philippines. Previous studies in disturbed landscapes in Benguet where the human population is large and increasing, and agricultural activities are expanding,

*Corresponding author
Email Address: aareginaldo@up.edu.ph
Date received: August 13, 2021
Date revised: November 23, 2021
Date accepted: December 12, 2021

KEYWORDS

agriculture, biodiversity, endemic species, pine forest, montane broad-leafed forest, native mammals, pest rodents, Philippines

have been limited in scope (e.g., Reginaldo and Ong 2020; Reginaldo and de Guia 2014), so that we have little information about mammal species in the patchwork of disturbed habitats that predominate in the southern portions of the Central Cordillera (Heaney et al. 2016, 2006 ; Rickart et al. 2016;. Given the likely vulnerability of native species to habitat modification, there is an urgent need to understand the effects that disturbance has on native species, especially the ability of forest fragments in mixed-use urbanized areas to support native fauna.

The small non-volant mammal fauna in the Central Cordillera is diverse and includes many species endemic to this region (Heaney et al. 2016; Rickart et al. 2016, 2011a). While it has been inferred that this fauna evolved along with past natural disturbances so that species can tolerate some disturbance (e.g., Rickart et al. 2021; 2011b), many species are dependent on healthy natural forests to survive. At high elevations in the Central Cordillera, especially above about 1800 m elevation, large tracts of montane forest remain (Fernando et al. 2008) and serve as a refuge for native species (Heaney et al. 2016, 2005). At elevations between about 1000 m and 1800 m, the areas believed to have once been covered by an extensive broad-leafed montane forest have been replaced by pine forests and grassland areas due to human activities, especially by burning (Kowal 1966; Whitford 1911). Remnants of the original montane forest remain, occurring as patches of broad-leaf vegetation along gullies and streams (Kowal 1966). In recent times, agricultural expansion has continued to threaten the remaining natural habitats (Reginaldo and de Guia 2014; Fernando and Cereno 2010; Heaney et al. 2006). Even the fire-dependent pine forests have been reduced into fragments in many places in Benguet (Reginaldo and Ong 2020).

Previous reports about small mammals have shown that native species have variable responses to disturbance. Some species persist or may have become locally extinct in heavily disturbed fragments (e.g., Reginaldo et al. 2013; Heaney et al. 2006;). Other native species thrive in disturbed habitats adjacent to montane forest fragments (Rickart et al. 2016; Reginaldo and de Guia 2014; Stuart et al. 2007), with some of them, perhaps surprisingly, more abundant in fairly heavily disturbed habitats than in the less disturbed habitats (e.g., Rickart et al. 2011b). Pine forest fragments in urban areas, such as those in Baguio City and its vicinity, are surrounded by extensive residential and agricultural areas and have been shown to support three to four native species (Reginaldo and Ong 2020; Reginaldo et al. 2013). Those previous studies found some evidence that the presence of native species in these disturbed habitats was tied closely to the presence of patches of remnant broad-leafed montane forest within those fragments. The native species recorded in such habitats include Cordillera pine forest mouse (*Apomys abrae*), Cordillera striped shrew-rat (*Chrotomys whiteheadi*), large Luzon forest rat (*Bullimus luzonicus*), common Luzon forest rat (*Rattus everetti*), and least Philippine forest mouse (*Apomys musculus*). Coexisting with these species are three non-native species; two were non-native pest rats, namely spiny rice-field rat (*R. exulans*) and Oriental house rat (*R. tanezumi*), and the seemingly harmless Asian house shrew (*Suncus murinus*).

We sought to determine patterns of presence and absence of small, non-volant mammals and to describe how they use available habitats in mixed-use urbanized disturbed habitats that predominate over much of Benguet Province in the vicinity of Baguio City. We conducted an extensive survey along the borders of three pine-dominated forest fragments from January to March 2019. At each of our three study areas, we trapped mammals in three habitat types: montane broad-leafed forest patches, pine stands, and agricultural areas. In this paper, we show that native and non-native species are components of disturbed landscapes, and we demonstrate that patterns of occurrence are influenced by individual responses of small-mammal species to habitat modifications.

METHODOLOGY

Study Areas

We selected three pine-dominated forest fragments in Benguet province, northern Luzon Philippines: Lower Wangal and Puguis in the town of La Trinidad, and Ambiong Central (a.k.a. Busol Watershed) in Baguio City. Pine trees (*Pinus kesiya*) were the dominant tree species in all three fragments but there were sections of the fragments where broad-leafed plants (trees and shrubs) grew under the pine trees at much denser cover than other areas. Remnants of the original montane forest remained, occurring as patches or strips along gullies or streams. In places where pine trees were extensive, the lower vegetation consisted mostly of fire-tolerant grass (*Imperata, Miscanthus, Paspalum*), exotic forbs (*Ayapana*) shrubs (*Melastoma*), and ferns (*Pteridium*). The expansion of pine forest and replacement of the original montane forest in the Central Cordillera is believed to have been facilitated directly or indirectly by *shifting cultivation* or *kaingin* (Kowal 1966). In more recent times, commercial vegetable farming also play a role. In our three study areas, the pine trees were either planted or had grown on their own when the soil condition under the pine trees became favorable, i.e., the lower vegetation was cleared by of fire or clearing of vegetation (*de-weeding*).

La Trinidad and Baguio City are adjacent areas, and are the most highly urbanized places in the southern section of the Central Cordillera (Figure 1). At present, human settlements cover almost the entire town and city. Large tracts of pine forest remain around the town/city proper (Figure 1) and are managed as watersheds, communal forests, and forest reserves. Historical records report that these two areas once were pastureland, and the pine forests were exploited for pinewood (Reed 1999; Bagamaspad and Hamada-Pawid 1985). Commercial vegetable farming in La Trinidad began in the 1950s (Kowal 1966), and it continues today in many places, particularly adjacent to streams. In each study area, we selected a section of a pine-dominated forest fragment that had a patch of remnant montane forest and a nearby agricultural area (Figure 1). The pine forest occupied the remaining area of the forest fragment, whereas the agricultural habitat continue as agricultural area or residential area outside the forest fragments (Figure 1). The range of sizes of the patches varied from about 0.40 hectares to 0.60 hectares. We trapped in three habitat types: agricultural area (AGRI), pine stand (PINE), and broad-leafed montane forest (MONT; referred to below simply as "montane forest").. The total area we sampled ranged at the three sites from about 3.5 hectares to 5.0 hectares (Figure 1). This variation was brought by the difference in size of montane forest patch and adjacent pine and agricultural habitats in each study area.

Wangal, La Trinidad; ~ 1300 masl; 60 hectares. Our study area in Wangal was within the jurisdiction of Barangay Lower Wangal. It was part of private land managed by two households, one living adjacent to the pine stand and the other within the agricultural area. In the montane forest patch, several individuals of old pine trees (50 to 70 cm in DBH) grew along with broadleaf trees (e.g., *Ficus* spp. *Mallotus* sp., *Eurya* sp.), indicating that disturbances had occurred in the past, and the patch has regenerated since then. Under the canopy, forest plants (e.g., *Vanoverberghia sepulchrei*, *Elatostema* spp., *Begonia crispila, Schismatoglottis* sp., *Pneumatopteris* sp.) were present. The pine stand had a section where the montane patch adjacent was advancing. The vegetation of that place consisted of a mixed

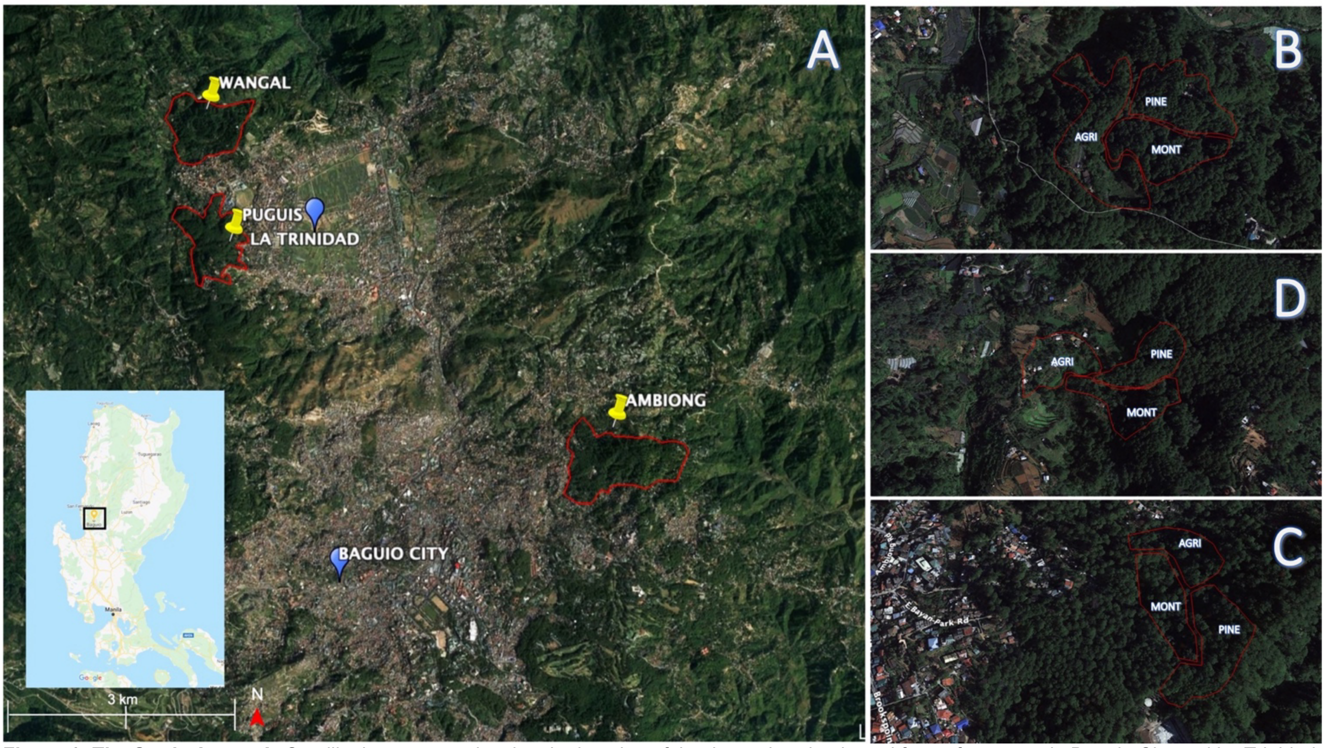

Figure 1: The Study Areas. A. Satellite image map showing the location of the three pine-dominated forest fragments in Baguio City and La Trinidad. Inset map shows the location of Baguio City in northern Luzon. **B–D.** Close up satellite image view of the each study area; outlined in red were the adjacent areas of the three habitats where we set the trapping grids. From top, Wangal, Puguis, and Ambiong. MONT = montane forest patch, PINE = pine stand, AGRI = agricultural area (Map data: Google, DigitalGlobe. *Accessed: February 2020*).

growth of shrubs (e.g., *Melastoma malabathricum*) and trees (*Ficus benguetensis* and *Macaranga* sp.). In another border of the pine that we sampled was a recreational house. The agricultural area we sampled consisted of a vegetable garden, a residential area, and a pasture area. Bordering the agricultural area were grasses and montane forest patches that occupied slopes, gullies, and stream banks. Based on the composition and structure of vegetation in the pine stand (e.g., the presence of several and scattered broad-leafed trees and tree ferns) and an advancing montane forest into the pine stand, this study area did not appear to have undergone recent major disturbance. During our study, disturbance, including human activities, were confined to the agricultural area and around the houses.

Puguis, La Trinidad; ~1300 masl; 50 hectares. The forest fragment in Puguis was managed by Benguet State University (BSU). Our study area was along the border of the fragment adjacent to vegetable gardens, which was within the jurisdiction of Sitio Ampasit. The montane forest patch occupied a slope and deep gully. Broad-leafed trees (e.g., *Ficus benguetensis* and *F. septica*) and giant bamboos (*Dendrocalamus* sp.) formed a dense canopy that almost prevented the growth of vegetation on the ground, except for coffee trees and citrus trees that according to local residents had been planted in the late 1970s. The presence of coffee trees and several old broad-leafed trees in the patch suggested that the area was cleared of vegetation prior to planting coffee seedlings. Most forest plants (*Chingia, Schismatoglottis, Elatostema*) grew only along the gulley, mostly on rocks where pockets of soil and organic materials had accumulated. In the pine stand, pine trees were relatively sparse in areas adjacent to grassland that bordered the vegetable gardens. A small section of the pine stand had been planted with coffee trees, but was overgrown by grass and shaded by pine trees (about 30 cm to 40 cm in DBH). The section of the pine stand adjacent to a stream separating it from a montane forest patch was covered by a mixed growth of pine trees, broad-leafed trees (e.g., *Ficus* spp. and *Saurauia* sp.), bamboos, tree ferns (*Sphaeropteris glauca*), and shrubs (*Melastoma malabathricum* and *Medinilla* sp.). The section of the pine stand adjacent to vegetable gardens had fewer pine trees. The agricultural area was cut by two streams and had been planted mostly with *sayote* (*Sechium*). According to locals, the place we surveyed used to be covered by broad-leafed trees but was converted into gardens in the 1990s. During our survey, part of that habitat remained as a strip of shrubby vegetation. Nearby were open areas with five distantly spaced residences. The structure of the montane forest patch and the much wider and extensive vegetable gardens in Puguis than in Wangal suggest that our study area in Puguis was more disturbed overall.

Ambiong, Baguio City; ~1500 masl; 80 hectares. The forest fragment in Ambiong was managed by the Baguio Water District. Extensive vegetable gardens and residential areas bordered the watershed. Our study area was adjacent to a small agricultural area that cut through a section of the watershed. The only permanent human dwelling adjacent to the habitats that we sampled was a guardhouse, but there was a large water reservoir (~1.4 ha) that was being constructed during the time of our survey. In the pine stand, pine trees were small (mostly 15 cm to 25 cm in DBH), and the lower vegetation consisted almost entirely of a mixed growth of grass (e.g., *Themeda* and *Miscanthus*) and the perennial composite *A. triplinervis* that together formed a dense cover of the ground. This condition of the pine stand suggested that the stand was relatively younger and more disturbed than the pine stands in the other study areas. The montane forest patch we surveyed was a rectangular patch covering a relatively flat area that had a dry stream-bed. Broad-leafed trees (e.g., *Ficus benguetensis, F. variegata*) of variable sizes formed a dense cover along the dry steam, and tall ginger (*V. sepulchrei*) dominated under the canopy. Another place was dominated by exotic broad-leafed trees (*Solanum mauritianum*) that formed a sparse canopy, which allowed the growth of grass and exotic forbs under the canopy. Several old pine trees (60 cm to 75 cm in DBH), the largest trees among our study areas, were scattered in the patch; their presence was also evidence of much earlier disturbance than those that we encountered during the survey. The agricultural area had four distinct areas: one section had been planted with *Sechium;* another had been planted with coffee; an open area densely covered by forbs (*A. triplinervis, Ageratina adenophora*, *P. aquilinum* var. *wightianum*); and an area cleared of weeds. Unlike in the other two study areas, there was no residential house nearby. Several gullies were present along the border adjacent to the pine stand and montane forest patch. There was also once a stream that cut through the agricultural area but had gone dry. Compared with the other study areas, the fragment in Ambiong was relatively the most disturbed overall for several reasons. The most important of these was caused by the annual removal of lower vegetation cover (a.k.a. *de-weeding*) every month of April to facilitate the establishment and growth of pine seedlings and other exotic trees (e.g. *Calliandra* and *Spathodea*) in the fragment. Just after our survey, the pine stand and a small section of the montane forest patch we sampled were cleared of weeds and native broad-leafed tree seedlings (e.g., *Mallotus* sp. and *Ficus* sp.). Many places along the border of the fragment were also used as vegetable gardens. In contrast to our other study areas, the patches of montane forests in Ambiong were relatively smaller in size and occurred along deep gullies such that they were isolated from each other by open habitats.

Trapping and Handling Animals

Small mammal trapping that mostly involved live-trapping was conducted from January to March 2019. To systematically document small-mammal presence and patterns of occurrence in each study area, we set three rectangular trapping grids (one in each of the three habitat types). The distance between any two grids varied (15 meters to 30 meters) because of differences in the shape and size of the remnant montane forests.

Each grid consisted of three line transects that were 15 meters apart and effectively constituted 45 trapping stations. In each line transect, trap stations were laid 10 meters apart. Earlier reports showed that small mammals in these disturbed landscapes had low to moderate abundance (Reginaldo and Ong 2020). To increase the chance of capturing species with low abundances, two traps were set 3-5 meters apart at each trapping station, so that in each grid, 90 traps were set per day of trapping. Each grid was sampled three times; we refer to these sampling times as trapping periods. Each trapping period consisted of two days of prebaiting followed by four days of trapping. In the first and second trapping periods, cage traps were used, whereas, in the third session, one of the two cage traps at each trapping station was replaced with a snap trap. Overall, grids contributed 9,720 trap-nights. Line transects were also set outside the grids during the third trapping period, and together contributed additional 873 trap-nights.

We adopted the type of baits and trapping techniques used elsewhere (e.g., Rickart et al. 2016, 1991; Heaney et al. 1989). In each trapping session, roasted coconut (coated with peanut butter) and live earthworms collected locally were used as baits in equal proportions. All traps were baited in the afternoon and checked the following morning. We followed standard procedures for handling live animals (Reginaldo and Ong 2020). Each animal was allowed to go into a funnel-shaped cloth bag designed to allow the animal to breathe and to minimize stress. While on the bag, body measurements (weight, hindfoot length, tail length, and an estimate of total length) were recorded. The measurements and diagnostic characters were compared against those listed in *The Mammals of Luzon* by Heaney et al. (2016). We note that the senior author has previously conducted studies of the small mammals of this region and prepared voucher specimens that were examined, and identifications were verified by the third author, an expert in the taxonomy of small mammals in the Philippines. For this study, the first author carefully recorded body measurements of animals during the fieldwork and the third author validated the identification. All live individuals were released at the sites of capture. A few individuals were snap-trapped; they were prepared as voucher specimens and were deposited at the Biology Laboratory of the University of the Philippines Baguio.

We report overall species richness by combining the species lists from all three grids. We also report species richness for each study area. We evaluate the adequacy of sampling among forest fragments using species accumulation curves. The presence/absence of species among the three habitat types was analyzed to infer how small mammals used the habitats. In grouping the small mammals, we followed others in their treatment of terms "native" and "non-native" species (Miller et al. 2008; Ong and Rickart 2008; Heaney et al. 1998). All of the native species are Philippine endemic species; as noted below,

Table 1: Occurrences of small non-volant mammals in the three study areas and each habitat type. MONT = montane forest patch, PINE = pine stand, AGRI= agricultural area; P = present, X = absent

SPECIES NAME	COMMON NAME	HABITAT TYPES								
		Wangal			Puguis			Ambiong		
		MONT	PINE	AGRI	MONT	PINE	AGRI	MONT	PINE	AGRI
Native										
Apomys abrae	Cordillera pine forest mouse	P	P	X	P	X	X	X	X	X
Apomys musculus	Least Philippine forest mouse	X	P	X	X	X	X	X	X	X
Bullimus luzonicus	Large Luzon forest rat	X	X	P	X	X	X	X	X	X
Chrotomys whiteheadi	Cordillera striped shrew-rat	X	P	P	P	P	P	P	X	X
Rattus everetti	Common Philippine forest rat	X	P	P	P	P	P	X	X	P
Total number of native species		1	4	3	3	2	2	1	0	1
Non-native										
Rattus exulans	Spiny rice-field rat	X	X	X	X	X	P	X	P	P
Rattus tanezumi	Oriental house rat	X	P	P	X	P	P	P	X	X
Suncus murinus	Asian house shrew	P	X	X	P	P	P	P	X	X
Total number of non-native species		1	1	1	1	2	3	1	1	1
Total number of species		2	5	4	4	4	5	3	1	2

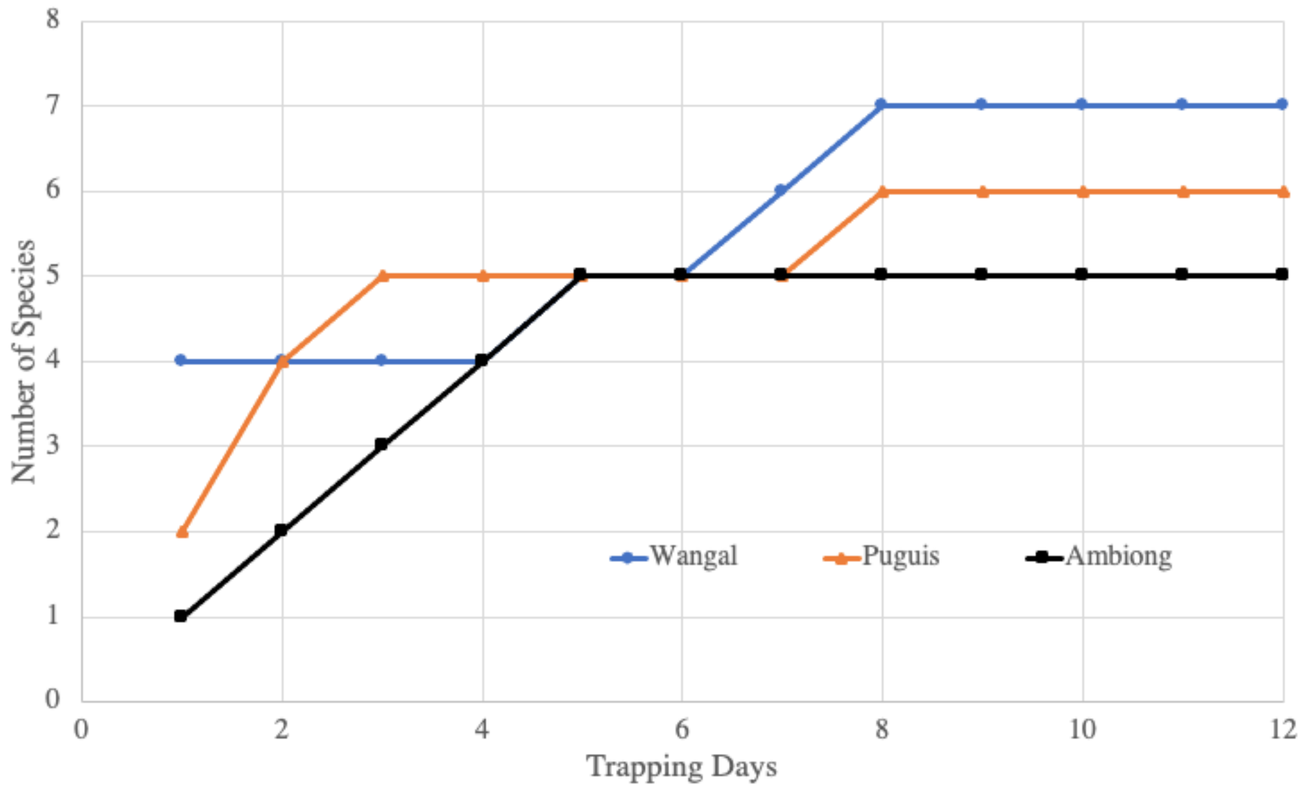

Figure 2: Species accumulation curves for each study area.

some of the species in our study are regional endemic species. In contrast, all of the non-native species are introduced species. An introduced species can be a pest, commensal or naturalized species. Whenever appropriate, we described a native species as endemic to a particular area or island, and a non-native as a pest or commensal.

RESULTS

Our entire survey recorded eight species (Table 1). Five of these are Philippine endemic natives, namely, *Apomys abrae*, *A. musculus*, *Bullimus luzonicus*, *Chrotomys whiteheadi*, and *Rattus everetti*, and the other three were non-native species, namely *R. exulans*, *R. tanezumi*, and *Suncus murinus*. We captured many individuals for some species, several individuals for others, and a single individual each for *A. musculus* and *B. luzonicus*. *Apomys abrae* and *C. whiteheadi* are species endemic to the Central Cordillera, *B. luzonicus* is endemic to central and northern Luzon Island (Heaney et al. 2021), *A. musculus* endemic to Luzon, and *R. everetti* endemic to the Philippines. In contrast, the non-native species occur throughout the Philippines and much of SE Asia; the two non-native *Rattus* species are pests. Analysis of species accumulation curves for all three study areas showed that all curves reached an asymptote (Figure 2); thus the sampling effort was sufficient to document all resident species in each study area.

The highest number of species, with all species present but *R. exulans*, was recorded in Wangal (Table 1). The species accumulation curve for Wangal shows that four species were captured on the first day of trapping, and the other three species were caught gradually (Figure 2). No other species were captured during the last four days of trapping. *Apomys abrae* were recorded only in MONT, whereas *C. whiteheadi* and *R. everetti* were both captured in PINE and AGRI (Table 1). *Suncus murinus* was only captured in MONT, represented by a single individual. *Rattus tanezumi* was captured in PINE and AGRI, with all individuals captured from stations nearest to the houses in our study area.

Our survey in Puguis recorded six species: three native species (*A. abrae*, *C. whiteheadi*, and *R. everetti*), and three non-native species (Table 1). The species accumulation curve for Puguis shows that two species were captured on the first day of trapping in Puguis (Figure 2), but the number of species quickly rose to five species on the third day, and the last species was captured on the eighth day of trapping (Figure 2). *Apomys abrae,* as in Wangal, was recorded only in MONT. In contrast, *C. whiteheadi,* and *R. everetti* were recorded from all three habitats (Table 1). *Rattus exulans* was recorded only in AGRI, whereas *R. tanezumi* was in PINE and AGRI. *S. murinus* was present in all three habitats (Table 1).

The lowest number of species, five of the eight species, was recorded in Ambiong. The native species present were *C. whiteheadi* and *R. everetti*, and all three non-native species were recorded (Table 1). The species accumulation curve for Ambiong shows that on the first day of trapping, only one species was captured (Figure 2). The other four species were added one species per day over the next four days, and no additional species were captured from day six to twelve (Figure 2). *Chrotomys whiteheadi*, with a single individual, was captured from MONT, whereas *R.* everetti was captured from AGRI (Table 1). *Rattus exulans* was recorded from both AGRI and PINE, whereas the other two non-native species were captured only from MONT (Table 1).

Two other mammal species were reported to us by local people: the northern Luzon giant cloud rat (*Phloeomys pallidus*) and a civet. It was reported to us that cloud rats often enter the houses near the forest fragment in Ambiong. In the MONT in Puguis, we often encountered civet droppings, which we suspect to be from the common palm civet (*Paradoxurus philippinensis*). Local gardeners in Puguis reported that they often captured civets in the area. In Wangal, we also encountered a roost of about ten individuals of Luzon pygmy fruit bat (*Otopteropus cartilagonodus*) on a *Ficus* tree, overgrown by a vine (*Passiflora edule*).

DISCUSSIONS

Species presence in disturbed Cordillera landscapes

The analyses of species accumulation curves from our trapping effort suggest that we may have documented all possible small non-volant mammals in all three study areas, representing a full list of all possible species that inhabit heavily disturbed landscapes in the southern Cordillera at an elevation that ranged from about 1300 masl to 1500 masl. All eight species of small non-volant mammals, five native and three non-native species, documented in our study have previously been reported for Benguet (e.g., Heaney et al. 2016; Reginaldo and de Guia 2014), including those that were reported in the early 1900s (e.g., Hollister 1913; Miller 1910). The lack of arboreal traps in our study, however, may have missed an arboreal species, *Apomys microdon*, a wide-ranging Luzon species (Heaney et al. 2016) that was recorded on nearby Mt. Sto Tomas (2200 masl; Reginaldo and de Guia 2014) southeast of our study areas.

Three native species, *Apomys abrae*, *A. musculus,* and *Chrotomys whiteheadi,* and the two non-native pest species *R. tanezumi* and *R. exulans* were reported from Baguio City (e.g., Camp John Hay and Irisan) between 1905 and 1907 (Hollister 1913; Miller 1910). *Apomys abrae* was also reported from the nearby town of Sablan in the 1940s based on collections deposited at the Field Museum of Natural History (Heaney et al. 2011; Sanborn 1952). Notably, the capture of *A. musculus* in Camp John Hay in the 1980s (Musser 1982) and in 2013 (Reginaldo et al. 2013) shows that this species has persisted in that area since it was first reported in the early 1900s (Miller 1910). More recent and focused surveys in Baguio/La Trinidad area have also confirmed the presence of these species, as well as the three others, *R. everetti*, *B. luzonicus,* and *S. murinus* (Reginaldo and Ong 2020; Reginaldo et al. 2013). The persistence of native species in these heavily disturbed landscapes is quite remarkable because native species are generally dependent on natural forest habitat.

Our record of native species among the three study areas and records from previous studies suggest that all species, except *B. luzonicus* and *A. musculus,* are possibly present in pine forest fragments in Benguet or in the southern Central Cordillera. However, the notable differences in the number and type of species across the three study areas and the levels or forms of disturbance present in each study area provide some insights into the role of habitat quality on small mammal occurrences in pine forest fragments. The privately-owned forest fragment in Wangal, La Trinidad, which had a relatively small vegetable garden and cattle pastureland, had two to three more native species than the other study areas, suggesting that the quality of habitats in Wangal may be more favorable for native species. Meanwhile, the species assemblage in Puguis represents a different scenario. Recent disturbance (clearing and reducing the original montane forest into small patches) and the extensive agricultural activities may have eliminated other native species, leaving only three native species. Notably, the capture of only two individuals of *A. abrae* in an area much further from the agricultural area and different from the capture sites of the two former species (unreported observation) suggests that it barely tolerated the habitat conditions in Puguis. Meanwhile, the case for Ambiong, which only had two native species, may represent an example of a more serious effect of disturbance on small mammals. The present condition in Ambiong was quite alarming for a forest fragment that is considered as a watershed and has been under active management. The comparably poor assemblage of native species in Ambiong may have been caused by excessive disturbances evident in the present structure of the forest fragment. Among those that we can mention may include past agricultural and pine logging activities and more recent activities such as clearing of weeds and gardening that significantly reduced the sizes of montane forest patches (see Methods). The construction of permanent structures (e.g., pumping stations and water pipes) and encroaching residential areas may also contribute to the present threats to native species. The demand for water by the nearby commercial farms and residential areas (La Trinidad and Baguio City at large) may have also affected water availability. In our study areas, two streams used to pass through the montane forest patch and agricultural area but they had gone dry. On a lighter note, earlier reports have inferred that native species can recover along with forest regeneration (e.g., Rickart et al. 2011b; Ong and Rickart 2008), and this may be possible for the mammals in Ambiong if appropriate intervention is implemented.

Habitat Use by Small Mammals

Records of occurrence among the three habitat types provide insights into species' response and use of habitats. In our study, differences in the patterns of occurrence of small mammals suggest that each species may be variably affected by disturbances associated with each habitat type. Surveys along gradients of habitat disturbance in the Central Cordillera reveals that native small-mammal communities are affected by habitat quality, often predictably structured along a gradient of habitat quality from pristine condition to heavily disturbed (Rickart et al. 2011b; Heaney et al. 2016). The various species we recorded may resemble one of the proposed type of animals in urban areas, such as *urban avoiders* and *urban exploiters* (Elmqvist et al. 2008; Blair 1996). With reference to disturbance, similar terms such as *disturbance avoiders* or *disturbance exploiters* may also be used. Gonzales and Dans (1997) also proposed these terminologies: *tolerant species*, *intolerant species*, and *colonizing species*. Avoidance or exploitation of disturbed habitats by various species of small non-volant mammals along a spectrum of habitat condition have been implied in reports from various areas (e.g., Umetsu and Pardini 2007; Pardini 2004; Dickman and Doncaster 1987).

The occurrence of several of the species in two or three habitat types, especially the two native species (*C. whiteheadi* and *R. everetii*) suggest that small non-flying mammals move between the habitat types. The movement of small mammals between areas of adjacent and disturbed habitats has been reported (e.g., Reginaldo and Ong 2020; Stuart et al. 2016, 2007). We did not measure home ranges, but earlier studies provide quantitative estimate of home ranges for some native and non-native pest species (see Heaney et al. 2016 and literature cited therein; Stuart et al. 2007; Balete and Heaney 1997).

The native species *A. abrae, C. whiteheadi,* and *R. everetti* are known to have a stronger tolerance for disturbance than other native species, often occurring in disturbed habitats adjacent to montane forests (e.g., Rickart et al. 2016, 2011a; Miller et al. 2008). Our results support this observation, and we show that these species can tolerate disturbance even more than previously asserted. Our results, however, suggest that *Apomys abrae* seemed to have a lower tolerance for disturbance than the other two species, occurring almost only in remnant montane forests and with the possibility that it had become locally extinct in Ambiong (Busol Watershed). In a similar survey that included several remnant montane forest patches, Reginaldo and Ong (2020) reported that *A. abrae* may be vulnerable to the effects of isolation because their populations aggregated in several montane forest patches that were surrounded by a matrix of open habitats. Endemic species that show tolerance to disturbance have also been reported for Philippine birds (see Gonzales and Dans 1997).

Chrotomys whiteheadi and *R. everetti* appeared to be widely distributed in our study areas , suggesting that they can tolerate various forms or levels of disturbances associated with each habitat type present. Notably, they occurred less often in the montane forest patches than in agricultural areas and pine stands, habitats that are expected to be heavily disturbed. However, this observation on *C. whiteheadi* was not surprising because this species has also been reported to use agricultural habitats, feeding on non-native earthworms and snails (Stuart et al. 2007; Joshi et al. 2004). Despite the apparent tolerance for disturbance of *C. whiteheadi* and *R. everetti*, we believe that the ability of these two native species to use pine stands and agricultural areas is supported by the presence of patches of remnant montane forest, including those that occupied streams or gullies. Testing this hypothesis will be the focus of our future papers. For the two other native species, *B. luzonicus* and *A. musculus*, their occurrences in only one study area, with a single individual each, suggest that they may have been strongly negatively affected by disturbance. In contrast, the occurrence of these species — along with *R. everetti* — from a heavily disturbed forest fragment in an urban area (Camp John Hay, Baguio City; Reginaldo et al. 2013) may suggest otherwise. But it appears that presence of an area that resembled the characteristics of montane forest (mixed growth of shrubs, broad-leafed trees and tree ferns) in Camp John Hay (Reginaldo et al. 2013) may explain their persistence in that fragment.

The possible effect of disturbances on all three non-native species was less predictable. While these species are generally known for their association with disturbed areas (Heaney et al. 2016; Ong and Rickart 2008;), our results suggest that factors in addition to the level of disturbance affect the distribution of these species across and within disturbed landscapes. Previous studies suggests that *Suncus murinus* is widely distributed across disturbed landscapes (e.g., Reginaldo and Ong 2020; Reginaldo et al. 2013), often associated with moist local conditions (Reginaldo and Ong 2021). Our results suggest that pine forests may also often provide habitat for *S. murinus*. *Rattus tanezumi* appears to be strongly associated with agricultural areas. However, its absence in the agricultural area in Ambiong and presence in the montane forest patch suggest that disturbance and some unknown factors – perhaps availability of food – affect the occurrence of this species in the disturbed landscape. Reginaldo and Ong (2020) suggested that a nearby human dwelling might be an important predictor of habitat use by this species, and our records reported here of *R. tanezumi's* capture sites support this hypothesis. For example, the record of *R. tanezumi* in the montane forest patch, but not in the agricultural area, in Ambiong may be due to the presence of a guardhouse near the montane forest patch (see Methods). Meanwhile, the occurrence of *R. exulans* among the habitat types appear to be influenced by factors different from *R. tanezumi*. Findings from other surveys in the Central Cordillera show that *R. exulans* is associated with pine forests and agricultural habitats (e.g., Heaney et al. 2016; Reginaldo and de Guia 2014) or more specifically in habitats that were recently burned (Rickart et al. 2016) or regularly cleared (Reginaldo et al. 2013) or pine forest with dense undergrowth of exotic grass and forbs (Reginaldo and Ong 2021).

CONCLUSIONS AND RECOMMENDATIONS

Our study has shown that pine-dominated forest fragments with remnant montane forest patches still support native species of small non-volant mammals. It is quite remarkable to find native species of small mammals to thrive in such small pockets of what used to be large tracts of montane forests in the Central Cordillera. The species we documented, however, includes only those that have strong tolerance for disturbance. While it is generally known that some native species have this ability, we provide evidence that *C. whiteheadi* and *R. everetti* can tolerate persistent heavy disturbance more successfully than previously demonstrated, and *A. abrae* may only tolerate moderate disturbance. We have also shown that these disturbed landscapes are habitat for non-native pest species, variably occurring in all three habitat types but less often in montane forest patches.

Having investigated several forms of disturbances, we believe that our observations here may also be likely true in other pine-dominated forest fragments in the Central Cordillera. The presence of small mammals in forest fragments calls for conservation of native species and control of non-native species. Native species do little harm to humans, whereas non-native rats are known to cause great damage to crops and stored food. Having shown that native species are present in the heavily disturbed pine forest fragments, we note that improving the quality of habitats in watersheds, nature reserves, and communal forests may be achieved by following appropriate interventions. We found indications that montane forest patches can regenerate and expand, such that forest regeneration may be facilitated by various means. While planting of native trees may be an important form of intervention, preventing fire occurrence is at least as important. Fire kills broad-leafed tree seedlings and young trees in pine forests, preventing montane forest patches from advancing into adjoining open habitats. Current management practices in protected watersheds need to be reviewed, including the practice of clearing vegetation in pine forests. Laws and ordinances and the commitment of private individuals may protect the remaining forest fragments in mixed-use urbanized areas in the Central Cordillera, but measures designed to regulate the expansion of agricultural areas and encroachment of residential areas into forest fragments should also be developed.

Our research on the assemblage of small mammals in disturbed landscapes provides a starting point for studies of biodiversity in these systems. Investigating the role of native species in the regeneration of habitats through seed dispersal, elucidating the dynamics in competition between native and non-native pest species, and determining the feeding habits and population dynamics of native species are among the exciting topics for future research. We recommend that similar studies be done for other organisms (e.g., invertebrates and plants) and physical conditions (e.g., temporal changes in water availability) that affect pine forest dynamics.

ACKNOWLEDGMENTS

We thank the Barangay officials of Lower Wangal, Puguis, and Ambiong Central Baguio City, Sudy Hidalgo and Scott Esteban, Baguio Water District, Institute of Highland Farming Systems and Agroforestry at Benguet State University, and the Department of Environment and Natural Resources -CAR for permissions to conduct our study. For field and lab assistance, our sincere thanks to Narciso Arugay Jr., Enrico Jugadora, John Aaron Catungal, Mario Constantino, Alvin James Quebral, and Mark Gerald Mislang. Special thanks to Maverick Tamayo and Fulgent Coritico for assisting in plant identification. The research was supported by funding from the Cordillera Studies Center of the University of the Philippines Baguio and the Protect Wildlife Dissertation Support by the United States Agency for International Development (USAID).

CONFLICTS OF INTEREST

There is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

AA Reginaldo, PS Ong, and LR Heaney formulated the study. AA Reginaldo performed the fieldwork. AA Reginaldo and LR Heaney wrote the manuscript.

REFERENCES

Bagamaspad A, Hamada-Pawid Z. A people's history of Benguet Province. Baguio City: Baguio Printing and Publishing Company, 1985.

Balete DS, Heaney LR. Density, biomass, and movement estimates for murid rodents in mossy forest on Mount Isarog, Southern Luzon, Philippines. Ecotropica 1997; 3:91–100.

Blair, RB. Land use and avian species diversity along an urban gradient. Ecol Appl 1996; 6(2): 506-519.

Dickman CR, Doncaster CP. The ecology of small mammals in urban habitats. I. populations in a patchy environment. J Anim Ecol 1987; 56:629–640.

Elmqvist T, Alfsen C, Colding J. Urban Systems. In: Fath B, ed. Encyclopedia of Ecology (Second Edition), 2008:452–458.

Fernando ES, Cereno RP. Biodiversity and natural resource management in the Mt Pulag National Park. In: Lapitan PG, Fernando ES, Suh MH et al. eds. Biodiversity and Natural Resources Conservation in Protected Areas of Korea and the Philippines. ASEAN-Korea Environmental Cooperation Unit, Seoul National University, Korea, 2010: 120–177.

Fernando ES, Su MH, Lee J, Lee DK. Forest formations of the Philippines. Seoul: ASEAN-Korea Environmental Cooperation Unit. 2008. 232 p.

Gonzales JCT, Dans ATL. Ecology and distribution of vertebrate fauna of Mount Makiling Forest Reserve. In: Dove MR and Sajise PE, eds. The Condition of Biodiversity Maintenance in Asia. USA: East-West Center, 1997: 203–231.

Heaney LR, Heideman PD, Rickart EA, Utzurrum RB, Klompen JSH. Elevational zonation of mammals in the central Philippines. J Trop Ecol 1989; 5:259–280.

Heaney LR, Balete DS, Dolar ML, Alcala AC, Dans ATL, Gonzales PC. Ingle NR, Lepiten MV. Oliver WLR, Ong PS, Rickart EA. Tabaranza Jr, BR, Utzurrum RCB. A synopsis of the mammalian fauna of the Philippine islands. Fieldiana Zool; 1998 8:1-61.

Heaney LR, Balete DS, Gee GA, Lepiten-Tabao MV, Rickart EA, Tabaranza Jr BR. Preliminary report on the mammals of Balbalasang, Kalinga Province, Luzon. Sylvatrop 2005; 13(1&2):51–62.

Heaney LR, Balete DS, Sarmiento J, Alviola PA. Losing diversity and courting disasters: the mammals of Mr. Data National Park. Haring Ibon 2006; 25:15–23.

Heaney LR, Balete DS, Rickart EA, Alviola PA, Duya MR, Duya MV, Veluz MJ, Vande Vrede L, Steppan SJ. Seven new species and a new subgenus of forest mice (Rodentia: Muridae: *Apomys*) from Luzon Island. Fieldiana 2011; 2:1–60.

Heaney LR, Balete DS, Rickart EA. The mammals of Luzon Island: biogeography and natural history of a Philippine fauna. USA: Johns Hopkins University Press, 2016.

Hollister N. A review of the Philippine land mammals in the United States National Museum. Proc US Natl Mus, 1913; 46: 299-341.

Joshi RC, Gergon EB, Aplin KP, Singleton GR, Martin AR, Cabigat JC, Cayong A, Desamero MV, Sebastian LS. Rodents and other small mammals in Banaue and Hungduan rice terraces, Philippines. International Rice Research Notes, 2004; 29: 44–46.

Kowal NE. Shifting cultivation, fire, and pine forest in the Cordillera Central, Luzon, Philippines. Ecol Monograph 1966; 36:389–419.

Miller, GS Jr. Descriptions of two new genera and sixteen new species of mammals rom the Philippine Islands. Proc US Nat Mus 1910; 38:3391–3404.

Miller RW, Stuart AM, Joshi RC, Banks PB, Singleton GR. Biology and management of rodent communities in complex agroecosystems – rice terraces. In: Singleton GR, Joshi RC, Sebastian LS, eds. Philippine Rats: Ecology and Management. Philippine Rice Research Institute, 2008: 25–36.

Musser G. Results of the Archbold Expeditions, no 108: the definition of *Apomys,* a native rate of the Philippine Islands. Am Mus Novit 1982; 2746: 1–43

Ong PS, Rickart EA. Ecology of native rodents in the Philippines. In: Singleton, GR, Joshi RC, Sebastian LS, eds. Philippine Rats: ecology and management. Philippine Rice Research Institute, 2008: 101–115.

Pardini R. Effects of forest fragmentation on small mammals in an Atlantic Forest landscape. Biodiv Conserv 2004; 13:2567–2586.

Reed RR. City of Pines: the origins of Baguio as a colonial hill station and regional capital. A-Seven Publishing. 1999.

Reginaldo AA, Ballesteros VF, Gonzales PV, Austria CM. Small non-volant mammals of forest patches in Baguio City, Luzon Island. Asia Life Sci 2013; 22:131–139.

Reginaldo AA, de Guia APO. Species richness and patterns of occurrence of small non-flying mammals of Mt. Sto. Tomas, Luzon Island, Philippines. Philipp Sci Lett 2014; 7(1):34–44.

Reginaldo AA, Ong PS. Small mammal–microhabitat associations in a disturbed landscape in northern Luzon, Philippines. Philipp Sci Lett 2021; 14(1): 51–64.

Reginaldo AA, Ong PS. The habitat structures in a lower montane forest fragment in Luzon Island, Philippines. Philipp Sci Lett 2020; 13(2):81–94.

Rickart EA, Heaney LR, Utzurrum RCB. Distribution and ecology of small mammals along an elevational transect in southeastern Luzon, Philippines. J Mamm 1991; 72:458–469.

Rickart EA, Heaney LR, Balete DS, Tabaranza BR Jr. Small mammal diversity along an elevational gradient in northern Luzon, Philippines. Mamm Biol 2011a; 76:12–21.

Rickart EA, Balete DS, Rowe RJ, Heaney LR. Mammals of the northern Philippines: tolerance for habitat disturbance and resistance to invasive species in an endemic fauna. Divers Distrib 2011b; 17:530–541.

Rickart EA, Balete DS, Alviola PA, Veluz MJ, Heaney LR. The mammals of Mt. Amuyao: a richly endemic fauna in the Central Cordillera of Northern Luzon. Mammalia 2016; 80(6):572–592.

Rickart EA, Heaney LR, Balete DS. Mammals of Mt. Pinatubo, Luzon Island, Philippines: extreme resilience following catastrophic disturbance. Philipp J Sci 2021; 150:121–133.

Sanborn CC. Philippine Zoological Expedition 1946-1947: Mammals. Fieldiana Zool 1952; 33:89–158.

Stuart AM, Prescott CV, Singleton GR, Joshi RC, Sebastian LS. The rodent species of the Ifugao Rice Terraces, Philippines, target or non-target species for management? Int J Pest Manag 2007; 53(2):139–146.

Stuart AM, Prescott CV, Singleton GR. Can a native rodent species limit the invasive potential of a non-native rodent species in tropical agroforest habitats? Pest Manag Sci 2016; 72(6):1168-1177.

Umetsu F, Pardini R. Small mammals in a mosaic of forest remnants and anthropogenic habitats – evaluating matrix quality in an Atlantic Forest landscape. Landsc Ecol 2007; 22:517–530.

Whitford HN. The forests of the Philippines. Part I: forest types and products. Manila: Philippine Bureau of Forestry Bulletin 10, 1911. 94 pp.