ARTICLE

Species richness and patterns of occurrence of small non-flying mammals of Mt. Sto Tomas, Luzon Island, Philippines

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A faunal study conducted across a disturbance gradient in Mt. Sto Tomas (1,980 to 2,200 meters above sea level), in southern Cordillera Luzon Island, Philippines, recorded nine species of small non-flying mammals. Six are endemic to the Philippines, four of which are only found in northern Luzon. Three species, including one shrew and two murids, are non-native species. This assemblage does not represent full diversity and is comparably lower than in other areas in the Cordillera; most of the species accounted for here represent the southernmost records for the Cordillera. The measure of abundance supports the general patterns of occurrence of native and non-native species as affected by varying degrees of habitat disturbance, wherein the native species are generally restricted and more common in intact forest habitats and the non-native species preferring disturbed to highly disturbed habitats. In addition, the results strongly support the hypothesis that some native species respond to different levels of disturbance differently from each other. There is also a strong indication that different responses are also exhibited by individual species of non-natives. It is recommended that studies should be conducted using a similar methodology that is employed here to verify the latter observation.

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Email Address: arisreginaldo@yahoo.com
Submitted: September 9, 2013
Revised: January 9, 2014
Accepted: January 10, 2014
Published: February 9, 2014
Editor-in-charge: Eduardo A. Padlan
Reviewer: Eric A. Rickart

INTRODUCTION

The rich diversity and high level of endemism of terrestrial mammals in the Philippines is associated with the geological history of the archipelago (Balete et al. 2009, Heaney 2002). Each modern day island, like Luzon Island, is a unique center of mammalian diversity (Rickart et al. 2011a). The size and geologic complexity of this island led to the formation of several subcenters of endemism, including the Central Cordillera highlands, the northern Sierra Madre and the Zambales Mountains (Rickart et al. 2011a, Balete et al. 2009, Heaney et al. 1998). In the latest account, there are at least 206 species of Philippine mammals, 117 (57%) of which are endemic (Heaney et al. 2013). For small non-volant species, 93 (90%) of 103 species are found to be endemic (Rickart et al. 2011b). Luzon supports at least 34 native species of non-volant small mammals of which 23 (68%) are endemic to the island (Balete et al. 2007). However, while information on the diversity and distribution of small non-volant mammals in the country has been growing for the past decades, the work is still far from completion. With the discovery that several subcenters of endemism exist within islands and that species have varied patterns and range of distribution, there is still a need to conduct more surveys in many areas.

Much of the available information on mammalian diversity in the Philippines comes from faunal surveys conducted along

KEYWORDS
small non-flying mammals, diversity, distribution, disturbance gradients

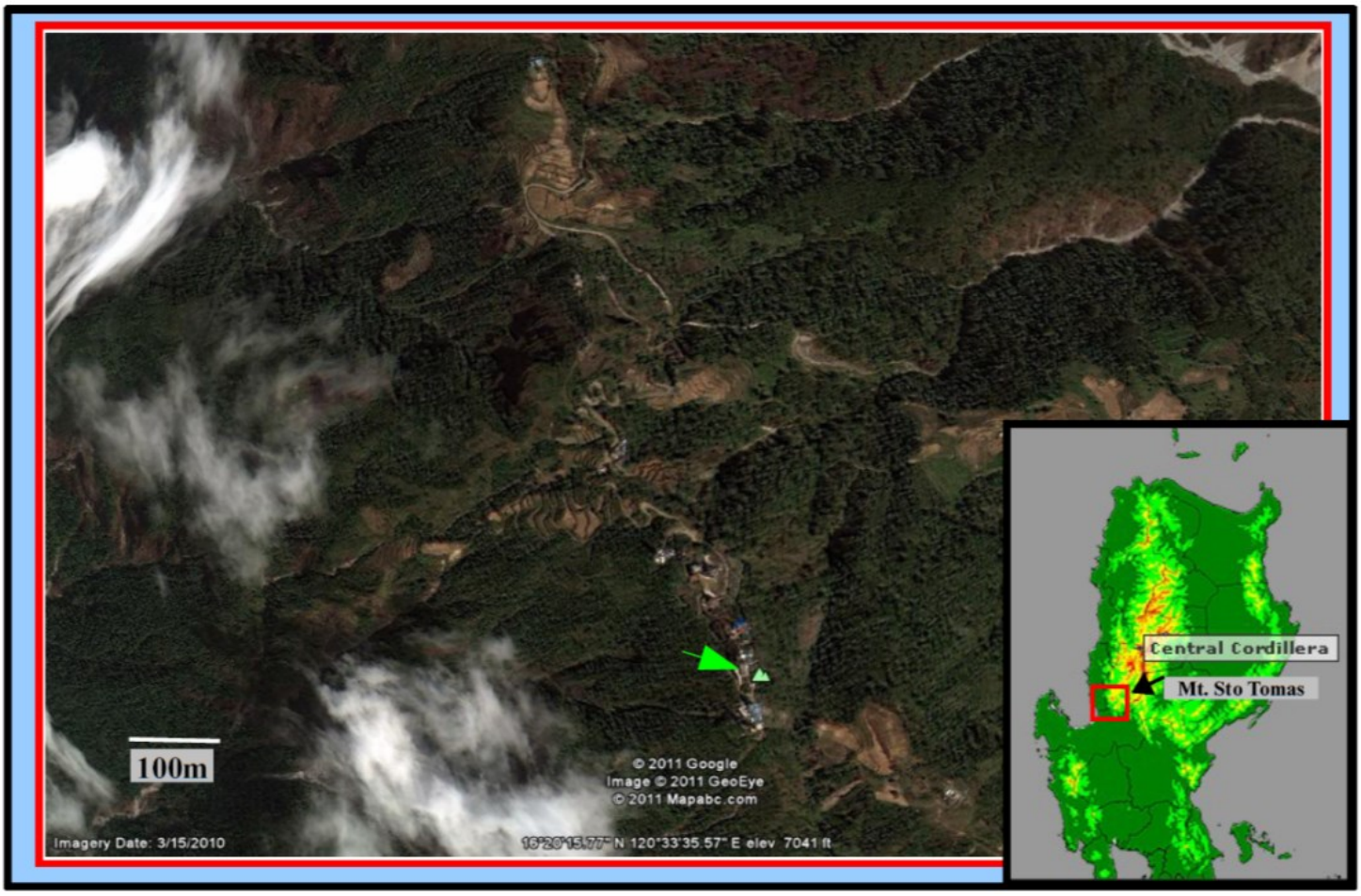

Figure 1. A satellite image of Mt. Sto Tomas showing the area where the survey was conducted. The light brown patches are portions of the forest that were converted for agricultural activities. At the peak (in green arrow), at 2,250 masl, are relay stations of several telecommunication and broadcasting companies. Inset map of Luzon Island shows location of Mt. Sto Tomas.

elevational gradients (e.g., Heaney et al. 2006, Rickart et al. 1993). The current hypothesis, that tries to explain differences in community composition of small non-volant mammals along elevational gradients, suggests that it is the amount of rainfall that has a great role in the availability of food in a community (Heaney 2002). Recently, there has been a shift to sampling habitats with varying levels of habitat disturbances along elevational gradients (e.g., Rickart et al. 2011b, Balete et al. 2009, Heaney et al. 2006*)*. These surveys led to observations that distinct patterns of occurrence exist between native and non-native species. In general, it has been observed that non-natives are primarily found in disturbed habitats while native species tend to be restricted to mature and intact forests (Rickart et al. 2007, 2011b*)*. A study, that investigated the tolerance of small mammals of the northern Philippines and invasive alien species for habitat disturbance, was conducted in four high-elevation mountains with varying levels of habitat disturbance along an elevation (Rickart et al. 2011b), reinforced these initial observations. Results of that study showed that native species richness declined with increasing levels of habitat disturbance with varying responses of individual species and concluded that endemic small mammal fauna in this area of the Philippines are adapted to varying levels of natural disturbance and thought to be resistant to disruption by invasive alien species. However, additional studies using similar methods or other designs must be conducted to test or further clarify and explain these tendencies of small non-volant mammals of the Philippines.

This study was conducted across adjacent habitats with varying levels of disturbances in Mt. Sto Tomas, northern Luzon, Philippines to determine the species richness and to assess patterns of occurrence and relative abundance of the small non-volant mammals in the area. This provides additional records on geographic distributions of small mammals known to be endemic in this area of the Philippines and further provide supporting observations on the patterns of occurrence of native and non-native small mammals of northern Philippines.

METHODOLOGY

Study Area

The 12-day sampling was conducted in December 2010 in Mt. Sto Tomas, Luzon Island, Philippines (Figure 1). This

Figure 2. a, The agricultural land, showing a cultivated area on top of a hill, with mossy forest on the left side; **b**, Mossy forest showing a tree almost covered by epiphytes; and **c**, An area within the pine forest showing numerous pine trees (*Pinus kesiya*) with understory vegetation dominated by grass with scattered shrubs and ferns.

mountain, with an elevation of 2,250 meters above sea level (masl), is part of the Cordillera region of northern Philippines. This mountain supports fauna and flora that represent species at the southernmost tip of the Cordillera region. The mountain summit consists of a few hectares of mossy forest extending up to 2,000 masl. At lower elevation is a pine forest which is continuous with the vast pine forest of the Cordillera region. Several patches of agricultural land lie within these forests.

These adjacent habitats (Figure 2), which lie at an elevation of 1,900 to 2,200 masl, represent the disturbance gradient that was sampled. The categories of habitat disturbance in the Cordillera region defined by Rickart et al. (2011b) were used in this study. The mossy forest was categorized as the least disturbed habitat, agricultural areas as the most disturbed, and the pine forest as at an intermediate level of disturbance. These habitats are represented as slightly disturbed, heavily disturbed, and moderately disturbed, respectively.

Mossy Forest (area: 1,000 m^2 – 20,000 m^2; elevation: 1,980 m to 2,200 m). These areas were generally undisturbed except along the edges adjacent to agricultural areas. Trees were stunted with heights ranging from 1 to 10 m and diameters at breast height (DBH) ranging from 2 cm to 15 cm. Leaf litter covered the ground, and moss covered the trunks and branches of trees, as well as fallen logs and rocks. Epiphytic ferns and orchids were common. Along the edges were shrubs (*Eupatorium*) and grass.

Pine Forest (area: 5,000 m^2 - 12,000 m^2; elevation: 1,900 m to 2,000 m). This habitat was dominated by stands of *Pinus kesiya.* Many young pine trees with heights of 1 m to 10 m and DBH of 3 cm to 20 cm were present, indicating that the area had not recently been disturbed by fire. However, in some areas, especially those adjacent to cropland, there were traces of recent burning. The understory vegetation was dominated by grasses, ferns, and some other smaller plants (e.g., *Melastoma, Alnus*). More broad-leaved shrubs (Compositae) were found on the edges of the forest especially those adjacent to agricultural land.

Agricultural Land (area: 2,500 m^2 - 10,000 m^2; elevation: 1,900 m to 2,200 m). The areas were mainly found on tops of hills that had formerly supported mossy forest. Most of the areas sampled were cultivated lands and were regularly planted with cabbage, broccoli and potato. During the sampling period, some areas had been planted and others were being cleared in preparation for the next planting. Areas dominated by grass surrounding the cultivated land, as well as abandoned areas that had not been planted recently, also were sampled. Traps were also set beside human settlements and at edges of roads. Two permanent houses are located within the sampling area. According to the locals, one of the houses was built in the 1940s and clearing of land for agriculture followed. Recently, slash-and-burn activities were banned and some of the areas previously cleared by fire were left uncultivated and are dominated by grass. Power transmission towers that were built in the 1980s are located on the peak.

Trapping and Collection of Mammals

Standard methods for trapping small non-volant mammals (Rickart 1993, Heaney et al. 2006) were used. There was a minimum of 800 trap nights per habitat over the entire duration of the field work, extending to more than a thousand trap nights to record movements of species across the three habitats. Species accumulation curves were plotted to determine if the sampling was sufficient to record all of the species within the area.

Live traps (23%) and snap traps (77%) were baited with earthworms (20%), roasted coconut coated with peanut butter (70%), or a combination of the two. Traps were mostly set on the ground (97%) especially in places where tracks, diggings and burrows were observed. Some traps were placed on fallen logs and branches of trees, and on top of climbing bamboos. Traps were randomly spaced, 3 to 5 meters apart. At least three sampling days were employed in each of the areas. Traps were set in

the afternoon, checked the following morning, and rebaited in the afternoon during the entire duration of the sampling.

Traps were set in the middle and at the edges of each of the habitat types. This was done to determine the tendency of a species to move between the habitats, to assess the tolerance of the native species for disturbance, and the tendency of the non-native species to invade.

Mammal Identification

Standard measurements of body weight, total length, head and body length, tail length, ear and hind foot length were taken for all individuals caught. Sex and general age category (juvenile, sub-adult, or adult) also were noted. Only live specimens that were confidently identified were released. All others were collected as voucher specimens and were deposited at the University of the Philippines Baguio.

Data Analysis

Chi-square test was used to assess patterns of proportional abundance of individual species (Rickart et al. 2007). Expected frequencies of occurrence were based on the total number of individuals captured across all localities, relative trapping effort (number of trap nights) at each locality, while assuming even distribution of species or group across the gradient. A test of proportion was also used to compare measures of abundance of native and non-native small non-volant mammals across the disturbance gradient (Figure 3).

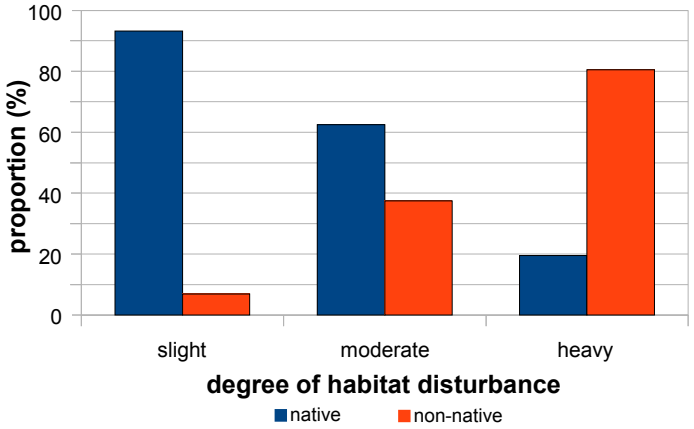

Figure 3. The relative proportions of native and non-native species across the disturbance gradients.

RESULTS

Species Richness and Abundance

A total of 137 individuals were captured after 3,075 trap nights (Table 1). There were nine species documented, including one non-native shrew (*Suncus murinus*), six endemic murid rodents (*Apomys abrae, A. datae, A. microdon, Bullimus luzonicus, Chrotomys whiteheadi* and *Rattus everetti*) and two non-native murids (*Rattus tanezumi* and *R. exulans*).

The number of species trapped approached asymptotes for each of the habitats (mossy forest, pine forest and agricultural land). For the entire accumulated trap nights, it started to plateau as it approached 2,000 trap nights and extended to the end of the survey, an indication that sampling for species richness, especially for the native, was sufficient in the area. In each habitat, early on, the number of species rose dramatically and then reached plateau at 500 trap nights for the mossy forest, and at 700 trap nights for both pine forest and agricultural land.

The trapping effort in the mossy forest had the highest trap success (5.58%) yielding 61 individuals representing eight species. The lowest trapping success was in the pine forest (2.91%) yielding 31 individuals (Table 1). Eight species, including one that was not found in the mossy forest, were captured in the pine forest. The trapping success in the agricultural land (45 captures; 5.04%) did not differ significantly from that in mossy forest, but only five species were recorded.

The study found more native species in the less disturbed habitats where disturbance is mainly confined along edges and in some areas with mixtures of pine. Although some native species were documented in the highly disturbed agricultural land, they were generally fewer in number. The relative abundance of native and non-native species varied across the disturbance gradient (Figure 3). A test of proportion showed significantly greater representation of native species in the mossy forest than in any of the pine forest ($Z=3.1$; $P<01$), or agricultural land ($Z=5.75$; $P<01$). Conversely, a higher proportion of non-native species was recorded in the agricultural land than in any of the mossy or pine forest.

Patterns of Occurrence of Native and Non-native Species

Difference in spatial distribution and relative abundance of species across the disturbance gradient (Table 1) resulted in significant heterogeneity in the local species assemblage ($\chi^2=274$; $df=16$; $P<0.005$). All native species, except *A. microdon,* were recorded in the disturbed pine forest, although at relatively lower numbers overall, compared to mossy forest. Two natives occurred across the entire gradient and these are *A. datae* and *C. whiteheadi*. However, out of the seven individuals of *A. datae* documented in the agricultural land, only one individual was captured from the middle of the cropland; the rest were captured along the edge adjacent to the mossy forest. In the case of *C. whiteheadi,* three individuals were captured from the middle of the cropland and one at the edge. The relative abundance of these two native species is significantly higher than expected in the mossy forest ($\chi^2=30.21$; $P<0.005$ and $\chi^2=23.88$; $P<0.005$, respectively). Individuals of *Rattus everetti*, on the other hand,

Table 1. Small non-flying mammals across disturbance gradients in Mt. Sto Tomas, Luzon Island, Philippines.

Species Name	English Name	Habitat			Total	χ^2	P
		Mossy Forest *slightly disturbed*	Pine Forest *mod. disturbed*	Agricultural Land *heavily disturbed*			
Native							
Apomys abrae	Cordillera Pine forest mouse	0	3	0	3	5.65	<0.250
Apomys datae	Luzon Cordillera forest mouse	**27**	6	7[a]	40	30.21	<0.005
Apomys microdon	Small Luzon forest mouse	1	0	0	1	2.08	_
Bullimus luzonicus	Large Luzon forest rat	1	1	0	2	0.98	_
Chrotomys whiteheadi	Cordillera-striped shrew-rat	**17**	2	4[b]	23	23.88	<0.005
Rattus everetti	Common Philippine forest rat	**5**	**6**	0	11	5.44	<0.250
Total captures		51	18	11	80	33.00	_
Non-native							
Rattus exulans	Polynesian rat	6*	**10**	**18**	34	10.74	<0.005
Rattus tanezumi	Oriental house rat	2**	1	**15**	18	23.97	<0.005
Suncus murinus	Asian house shrew	2***	2	1	5	_	_
Total captures		10	13	34	57	80	
Overall trap captures		**61**	31	45	137	274	<0.005
No. of trap nights		998	1066	1011	3075		
Trap success		5.51	2.91	5.04	4.46		
No. of native species		5	5	2	_		
Number of species		8	8	5	_		

Capture frequencies greater than expected are indicated in bold font

* 4 individuals are found on the edge of the forest beside agricultural land; 1 individual in area with mixed Pines

** captured along the edge of the forest adjacent to the agricultural land

*** captured along the edge of the forest (with Pine trees) adjacent to the agricultural land

[a] 3 individuals were captured along the edge of the agricultural land beside the Mossy forest; 2 were from an open grass

[b] 3 were captured from middle of the agricultural land

were only recorded in the mossy forest and pine forest, and the relative abundances in these habitats are significantly higher than expected. For *Bullimus luzonicus*, it was uncommon in mossy and pine forest and was not recorded in the agricultural land.

For the non-native species, all were documented in all three habitats, with their presence in the relatively less disturbed habitats highly notable. Only one individual of *R. exulans* was recorded from the middle of the mossy forest and the rest were captured along the edge of the forest and in areas where mixture of pine is present. This species was more abundant than expected in the pine forest and agricultural land (χ^2=10.74; P<0.005). Individuals of *R. tanezumi* recorded in the mossy forest were captured at the edges adjacent to cropland. Unlike *R. exulans*, individuals of *R. tanezumi* were only significantly more abundant than expected in agricultural land (χ^2=323.97; P<0.005). The less abundant *S. murinus,* on the other hand, was uncommon in all habitats, with records from the mossy forest restricted along edges where there was a mixture of pines.

DISCUSSION

Southern Cordillera Small Non-volant Mammal Fauna

The Mt. Sto Tomas study is the first comprehensive survey of small non-volant mammals in this area of the Cordillera, representing the southernmost record of the Northern Luzon fauna, and many are new geographical records. Three of the six native mammals, namely *Apomys abrae, Apomys datae* and *Chrotomys whiteheadi,* are endemic to the Central Cordillera of Luzon (Rickart et al. 2011a, Heaney et al. 2006). On the other hand, *Bullimus luzonicus* and *Apomys microdon* are endemic species of Luzon, while *Rattus everetti* is found throughout the Philippines (Heaney et al. 1998). However, compared to the recent records of small non-volant mammals further north in the central Cordillera, the assemblage recorded on Mt. Sto Tomas is less diverse. Some of the cordilleran species not recorded here include *Chrotomys silaceus, Crocidura grayi, Batomys granti, Rhynchomys soricoides, Archboldomys maximus, and Soricomys spp.* (Rickart et al. 2011a, Ong and Rickart 2008, Balete et al.

2012), and *Apomys musculus*, which was documented from a survey of a patch of pine forest (1,500 masl) about a kilometer northeast of Mt. Sto Tomas (Reginaldo et al. 2013). Even though this assemblage may not represent the full diversity of the mountain, because of the possible presence of other species at lower elevations, the mossy forest sampled represent the most intact and uppermost habitat (1,900 to 2,200 masl) of the entire mountain, so that it is likely that the native species were fully accounted for. In addition, forests at lower elevations are mainly pine forest along the eastern side and broadleaf forest along the west, where most areas are disturbed.

This study is highly comparable to surveys conducted in Balbalasang, Kalinga (Rickart et al. 2011a) and Mt. Amuyao, Mountain Province (Rickart et al. 2011a, Ong and Rickart 2008). Six out of the 11 native species (between 1,800 to 2,150 masl) documented in Balbalasang were recorded in Mt. Sto Tomas. Five out of the 14 native species documented on Mt. Amuyao were recorded in this study. A species documented on Mt. Sto Tomas, which was not recorded in Mt. Amuyao, Kalinga, is *A. microdon.* It is interesting to note the apparent absence of this species in that part of the Cordillera, although its presence in other parts of Kalinga may suggest that this species is found across the entire Cordillera region. According to Rickart et al. (2011a), the apparent rarity of this species may stem from its arboreal habits. The presence of *A. abrae* in Mt. Sto Tomas was also recorded at a lower elevation (1,900 masl), similar to the Mt. Amuyao and Balbalasang surveys. Another survey (Reginaldo et al. 2013*)* along a patch of pine forest (1,500 masl) in Baguio City, northeast and about a kilometer away from Mt. Sto Tomas, did not detect this species. These differences in the occurrence of the endemic species may be accounted for by how healthy the habitats are, as had been consistently observed in other surveys (Rickart et al. 2007). Most habitats in Balbalasang where the endemics were documented were all mature forests (Ong and Rickart 2008). In Mt. Sto Tomas, the most intact forests are mainly beside and near agricultural areas where significant disturbance in these areas may have affected other endemic species living in the mature forest.

Patterns of Abundance and Occurrence of Small Non-volant Mammals Along Disturbance Gradients

The inferred general habitat associations of native and non-native species are supported by the recorded occurrences of small non-flying mammals on Mt. Sto Tomas. Native species across local disturbance gradients in Luzon were found to be most diverse in relatively undisturbed habitats, tending to decline in both occurrence and abundance with increasing levels of disturbance (Rickart et al. 2011b, Rickart et al. 2007). Data suggest that some species can generally utilize any habitat, but more species and individuals can be supported by the less disturbed habitat such as mossy forest.

The presence of some native species in the heavily disturbed agricultural land on Mt. Sto Tomas is also consistent with the results of previous studies. The presence of *A. datae* in the middle of the cropland suggests that this species can tolerate considerable habitat disturbance. Elsewhere in the Cordillera region, this species is found to be generally common in least disturbed, or moderately disturbed, areas (Rickart et al. 2011a). The record of this species in a more disturbed area in one of the gradients in the study of Rickart et al. (2011a) and the observation in the present study may indeed suggest that this species can tolerate disturbance of a greater degree than what was initially speculated. *Chrotomys whiteheadi* is known to be highly tolerant of disturbance and may be locally common even in highly disturbed areas like croplands (Rickart et al. 2011a and 2011b, Rickart et al. 2007, Heaney et al. 2006).

The observations on other native species are consistent with the results of previous surveys. *Bullimus luzonicus* is usually uncommon and generally found in moderately disturbed or intact forest (Rickart et al. 2007; Heaney et al. 1999, 2006). *Rattus everetti* is generally abundant in second growth and pine forest, and uncommon in other areas (Ong and Rickart 2008); on Mt. Sto Tomas, several individuals were documented in the pine forest that is regularly burned (1 to 2 times a year) due to agricultural activity adjacent to the forest. The absence of *B. luzonicus* in the agricultural land indicates that it is less tolerant of disturbances than *R. everetti*; such was the case at most localities in the northern Cordillera (Rickart et al. 2011b). In this study, *A. abrae* was only documented in the pine forest adjacent to the mossy forest. This species is generally associated with intermediate disturbance levels, and is often most abundant in pine forest (Rickart et al. 2007, 2011a). The single individual of *A. microdon* from Mt. Sto Tomas was collected from the mossy forest. Other records from Luzon cannot confirm its real tendency because of low capture frequencies. A record in Balbalasang Kalinga (Rickart et al. 2011a) and its occasional presence in other mossy forests in Luzon Island (Balete et al. 2009) suggest that it has low tolerance for disturbance.

For non-native species, their existence is dependent on the degree of disturbance (Figure 2), being more abundant in, or restricted to, highly disturbed habitats. Some, including *R. tanezumi* and *R. exulans,* are known to be more widely distributed in croplands, brushy second growth and disturbed forest (Rickart et al. 2007). In many areas of the Cordillera, both species are common in second growth forest, pine forest, crop edge and along rice terraces, and are absent in mature broad-leaf forest (Rickart et al. 2011a, Ong and Rickart 2008). This study provides strong evidence that *R. exulans* tend to be more widespread and abundant than *R. tanezumi* in disturbed habitats adjacent to croplands. Several individuals also were recorded in the mossy forest primarily along the forest margins which were adjacent to agricultural and were also usually disturbed. Occurrence in forest fragments adjacent to cropland may reflect local movements and does not necessarily mean that this species can readily establish itself in the forest. Rickart et al. (2007) described this tendency as "due to numerical dominance". The observation that the six individuals of this species were captured from different

days of the entire survey suggests that this tendency is frequent. Our observations on the disturbance association of these two non-native murids are consistent with the results of a study in urban pine stands of Baguio City where *R. tanezumi* tend to be more common and widespread than *R. exulans* (Reginaldo et al. 2013).

The non-native shrew, *S. murinus,* although uncommon in this study, also exhibited the same tendencies as the other non-native species. *S. murinus* was found to be absent from most forests on most Philippine Islands (Balete et al. 2009; Rickart et al. 1993). This species has not been documented in recent surveys in the Cordillera (Rickart et al. 2011b). On Mt. Sto Tomas, individuals were recorded in all the habitats. The individuals recorded from the mossy forest were confined to edges of areas with a mixture of pine trees (indication of disturbance). This and their low number in the agricultural areas suggest that they may be more common in less disturbed areas. This species was common in a pine forest fragment in an urban setting (Reginaldo et al. 2013).

These tendencies of the non-natives documented here strongly support the hypothesis of Rickart et al. (2011b) that establishment and persistence of non-native species requires substantial and sustained disturbance. They also hypothesized that the local diversity of native small mammals also limits the spread of non-native species in forested habitats.

The new observations gathered here, about the tendency of native and non-native small (non-volant) mammals of the Philippines to be affected by varying levels of disturbance, suggest that each species of native small mammals has its own tendency or tolerance for disturbance. In the northern Philippines, while the range of natural habitat was determined as the most important predictor variable for disturbance response of native species, other factors or a combination of factors may be at play for these observed tendencies.

In the case of the effect of invasive alien species, while it becomes clear that based on data of occurrence, non-native species do not pose a serious threat to native small mammal community in this area of the Philippines, the role of parasites in mediating community processes cannot be eliminated. Evidence that supports this role of parasites is growing (Thomas et al. 2005), with the possible transmission of exotic parasites or disease from resistant non-native species to less resistant native host (Dowler et al. 2000). With this, one can actually include parasitism as an alternative explanation of the observed tendencies of the small mammals in the Philippines. These speculations can be tested through future studies.

SUMMARY AND CONCLUSION

Nine species of small non-volant mammals were recorded, six of which are endemic species. The assemblage had fewer species compared to other areas of the Cordillera. Most of the species recorded in this study are new records for Benguet, representing the southernmost limit for the Cordillera region.

This study examined the pattern of endemic and non-native species of small non-volant mammals in habitats with varying degrees of disturbance. The observed general tendencies are consistent with other studies. Although both groups of small mammals were observed to move across habitats, non-natives are indeed mainly restricted to disturbed areas. Data clearly showed that while a general pattern exists between native and non-native mammals, specific patterns are also exhibited by individual species. Among the native species, *C. whiteheadi* has the greatest tolerance for disturbance, even occurring in the most highly disturbed habitats.

There is also a strong indication that different species of non-native species respond differently. The abundant and widespread *R. exulans* tends to only reach disturbed areas of more intact and healthy forest, but is not adapted to such habitat.

This study further suggests that endemic small non-volant mammals are not easily displaced by the introduced species, especially in habitats with varying degrees of disturbance.

ACKNOWLEDGEMENTS

The authors would like to thank the Commission on Higher Education, in collaboration with the Office of the Vice-Chancellor for Research and Development of UP Diliman, for funding support through the Commission on Higher Education Science and Engineering Graduate Scholarship (CHEDSEGS) program. We would also like to thank Mr. Danny S. Balete, Dr. Lawrence R. Heaney, and Dr. Eric A. Rickart for confirming the identification of the species of mammals. For other inputs to the paper, we thank Dr. Elsie M. Jimenez and Dr. Candy L. Torres, and the many others who extended their invaluable support of the research.

CONFLICT OF INTEREST

No conflict of interest.

CONTRIBUTION OF INDIVIDUAL AUTHORS

Both authors did significant input to the form and content of the paper. For the data gathering, A. Reginaldo did all the fieldwork with assistance and supervision of AP de Guia.

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