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Occurrence and Habitat Use of Non-native Small Mammals in Upland Urban-Forest Environment in Northern Philippines

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ABSTRACT

In the Philippines, few researches have been conducted about small mammals in urban areas at high elevation, where forests remain and non-native pest species can proliferate. Previous studies in Baguio City, Benguet Province reported three non-native species. This study extended these prior surveys by sampling in 13 localities, employing standard trapping method to document the distribution of species in an urban-forest setting. In 4,711 trap nights, 94 individuals were captured, consisting of four non-native species: Rattus exulans, Rattus tanezumi, Mus musculus, and Suncus murinus. Analysis of occurrence and relative abundance of species showed that small mammal distribution varied among the habitats, and appeared that variation may have been related to differences in vegetation structure or a habitat's disturbance level. Rattus tanezumi was the most widespread, being especially common in backyard farms and in the public market. Suncus murinus was also widespread but less abundant than R. tanezumi. Rattus exulans was uncommon and restricted to certain area of a given habitat, particularly preferring weed-dominated areas. These suggest that non-native species are common and widespread in urban-forest setting but with apparent habitat preferences. The non-detection of native species is notable, suggesting that thorough studies can be done in the future.

Keywords: *habitat disturbance, non-native species, pest species, urban-forest environment, habitat use*

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INTRODUCTION

Human-related activities result in extensive modification of natural environment and confront organisms with a range of novel conditions (*Dickman and Doncaster 1987*). Changes such as these are known to affect spatial distribution of small mammals (*Harris 1981*) and lead to local extinctions of native species (*Harris 2009*). In the Philippines, habitat modification facilitates invasion of non-native species to natural habitats (*Ong and Rickart 2008; Rickart et al. 2011a*), and coexistence of native and non-native species often occurred in disturbed areas adjacent to or within forest habitats (*Rickart et al. 2016; Reginaldo and de Guia 2014*). Non-native species primarily occupy disturbed and degraded habitats, and studies on Luzon Island, Philippines have shown that non-native species do not invade intact forests (*Rickart et al. 2011a; Rickart et al. 2007*) or tend to be restricted to human-modified habitats despite the proximity of a forest (*Reginaldo and Ong 2020*). In complex agro-ecosystems in the lowlands, uplands, native and non-native species often coexist (*Stuart et al. 2007; Miller et al. 2008*). However, the full extent of the impacts of these human activities on the occurrence of small mammals and the specific factors that affect their spatial distribution have not been studied in the urbanized areas of the Central Cordillera- an area with large tract of forest and has the highest level of endemism of small mammals in the Philippines (*Heaney et al. 2016; Rickart et al. 2011b*).

In Baguio City, a large urban area (population ca. 350,000) in the Central Cordillera of Northern Luzon, local small mammal assemblages were previously studied in two pine forest habitats of varying degree of disturbance (*Reginaldo et al. 2013*). In that study, non-native species were present in the pine forest fragments. Native species of small mammals were also present, but were only recorded in the less disturbed fragment, in a place with abundant broad-leafed undergrowth. Information on the extent of distribution and habitat use of small mammals and the presence of native species in highly urbanized forest setting remain to be elucidated, as the scope and analysis on the specific responses of each species in prior studies was preliminary.

In this study, small mammals were surveyed at multiple sites, covering a gradient of habitat disturbance

represented by various habitats that ranged from patches of pine forests to a public market, the most altered urban environment within Baguio City. This research builds on earlier studies, enabling to examine specific response of non-native species to human activities. This study provides relevant information about occurrence and habitat use of small mammals in response to varying degrees of habitat disturbance caused by humans. Also, the results provide insights that help in the design of specific programs to control the population of the pest species within the specific conditions and according to the complexity of the habitats that are present in. By inference, this study also commented on the possible response of native species to human activities.

MATERIALS AND METHODS

Study Areas

Baguio City, Philippines is a highly urbanized city that lies in the southern portion of the Central Cordillera mountain range in Luzon Island, located at approximately 1,500 masl (**Figure 1**). In the early 1900s, most areas now covered by Baguio City were pastureland (*Reed 1976*), with grass and fern as dominant vegetation in open habitats. At present, pine trees were mainly concentrated in areas that was designated as forest reserves (e.g., Camp John Hay and Teachers Camp) or watersheds (e.g., Busol Watershed). For the past hundred years since the settlement of Americans (*Reed 1976*), the protection of certain areas, including Camp John Hay (CJH) Forest Reserve, allowed growth and proliferation of pioneer pine trees and establishment of some other tree species that were planted as part of reforestation programs. The management of forest reserves generally prevented the occurrence of fire, a natural agent that favors pine forests. Human settlements started to sprout probably about three decades ago (*Estoque and Murayama 2011*), and, to date, houses cover almost the entire city, including areas where hills are very steep, and some watershed and forest reserves are maintained and protected (**Figure 1**).

The climate in Baguio is divided into two distinct seasons: a rainy season and a dry season, with temperature that range from 15 to 23°C on average. The survey of small mammals was conducted in thirteen localities within Baguio City. These localities were grouped into four general habitat types: pine stands, residential areas, public market, and backyard farms (**Figure 1**). A backyard farm is maintained by a single household, and it is relatively smaller than the expanse of agricultural areas that are also found in several places in Baguio City. A qualitative description of each habitat and a qualitative

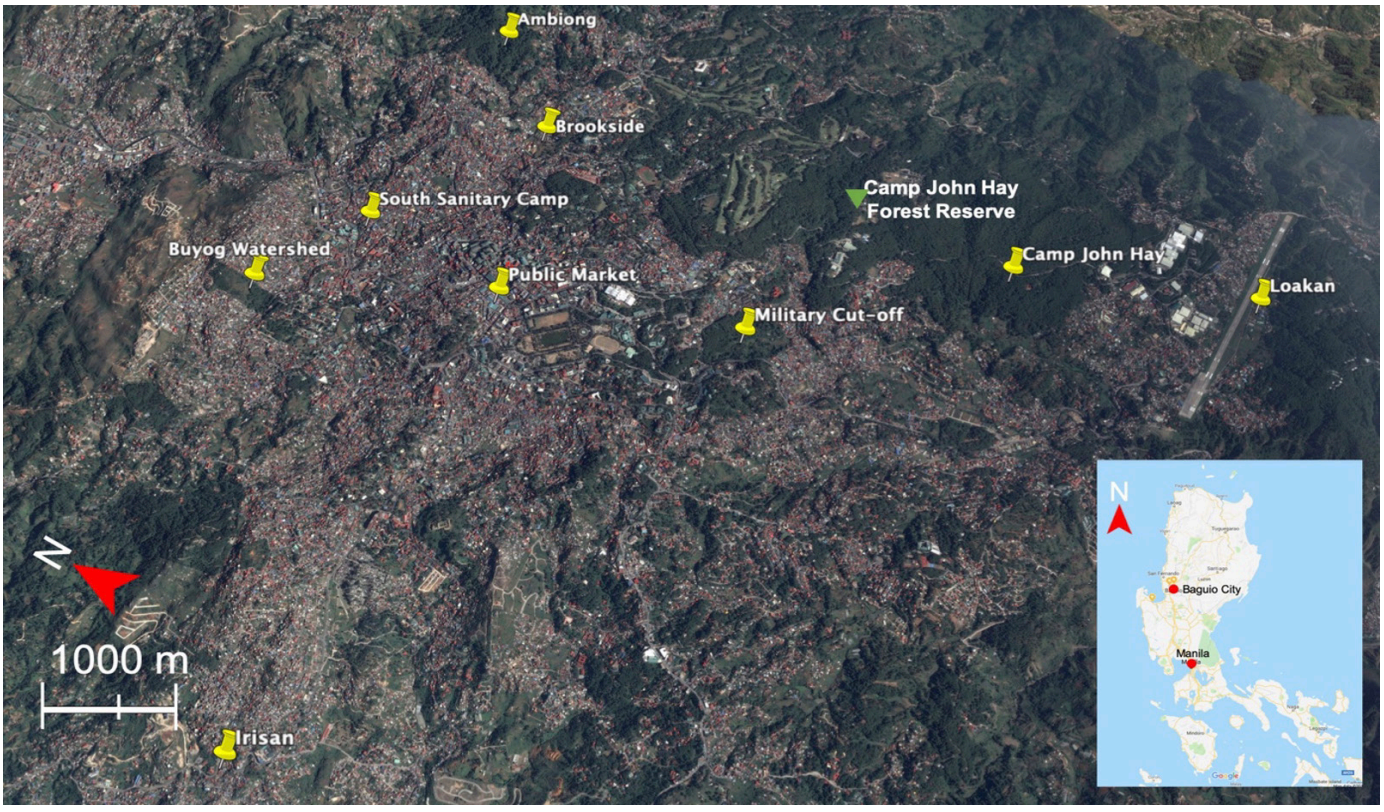

Figure 1. A satellite image of Baguio City showing the different study areas (Map data: Google, DigitalGlobe. Accessed: December 2014) (Inset map of the Philippines shows the location of Baguio City).

measure of levels of human activity were recorded during the survey. The following categories, developed according to form of human activity and associated disturbance, were used in the analysis of small mammal-habitat associations: minimal, low, high, and very high for the pine stand, backyard farms, residential areas, and public market, respectively.

Pine stands. Four localities were selected in sampling pine stands: Buyog Watershed, Busol Watershed (Ambiong), a forest fragment in Military Cut-off, and a section of a relatively large forest fragment in Camp John Hay (**Figure 1**). The watersheds are maintained by the Baguio Water District (BWD) and protected by the Department of Environment and Natural Resources¬ (DENR). The individual stands are several hundred meters apart (**Figure 1**) and are bordered by human settlements (**Figure 2**). The stands were consisted primarily of Benguet pine (*Pinus kesiya*), and the understory species were dominated by several species of grass (e.g., *Themeda, Paspalaum*), weeds (*Tithonia, Ayapana*) and fern (*Pteridium*). Ornamental plants were also planted in some localities. Several individuals of broad-leaf trees (e.g., *Ficus* and *Alnus*) and tree ferns (*Cyathea*) were also present. All of the pine stands were accessed by humans by varying degrees. Tree planting activities of pine trees and alder (*Alnus*) were a common activity in all pine stands. Economically important plants (*Thysanolaenia, Sechium, Colocasia* and *Coffea*) were also growing in two of the pine stands.

Buyog Watershed is a steep (nearly 45°) fragment of about 0.066 km^2 in area, covering hill in the northern section of the Baguio City. The pine trees primarily rest on limestone substratum. A relatively dense cover of pine trees was located at the lower and upper areas of the hill. Scattered pine trees and a distinct grass-dominated section covered the middle of the pine stand.

Busol Watershed in Barangay Ambiong is a large pine stand (around 0.600 km^2) that covers the peak of another hill in the northeastern section of the city. At the western side of the hill, residential buildings bordered the area, the same section where most pine trees were found.

The Military Cut-off pine stand lies at the southern slope of a wide plateau near the center of the city with about 0.170 km^2 in area. The stand covers most of this steep slope (around 45°) that descends over about 80 m; the tree cover is densest here. The relatively leveled areas consisted of a mix of large and smaller pine trees, and the open areas were covered with weeds, and grass. Roads almost bordered the entire area, and one side is adjacent to a thick residential area (**Figure 3**). Within the pine stand, one small building of BWD is used as laboratory. Alder (*Alnus*) and Calliandra (*Calliandra*), planted through tree-planting activities, are also common in the stand.

The pine stand in Camp John Hay is a large fragment of pine forest (0.500 km^2) separated by a road with the CJH Forest Reserve, a protected area of about 3.20 km^2. The place is managed by the DENR, where a research station (Watershed and Water Resources Research Center) is present. The pine trees grew on a less elevated hill and the protection of the pine and broad-leafed trees were evident through the present structure of the pine forest. Some areas were planted with vetiver grass (*Chrysopogon zizanoides*), a species of grass that is used to make native brooms (**Figure 2C**).

Backyard farms. Six localities with backyard vegetable and flower farms, situated in three barangays (South Sanitary Camp, Brookside, and Loakan), were selected. All farms, except one, were primarily planted with flowering plants instead of vegetables (**Figure 1**). Also, all sites, except the one that were planted with flowering plants, were surrounded by extensive residential areas (**Figure 3**).

The two backyard farms in barangay South Sanitary Camp are less than one kilometer apart. The first one is a small (only about 0.0001 km^2) vegetable garden in a vacant lot beside a river (Balili River). The garden was planted with beans, cabbage, and strawberry. Coffee (*Coffea*), banana (*Musa*) and sugarcane (*Saccharum*) were also planted. The other farm was a garden along the gulley of a hill (around 0.0005 km^2 in area) that was last used for gardening five years prior to the survey. A stream cuts through the area and the banks were terraced. According to the caretaker, the place used to be planted with vegetables; at the time of the study, it was covered with weeds such as wild sunflower (*Tithonia*) and *Alternanthera*. At another place, coffee trees had been planted. There is also an area with several pine trees; thriving underneath were wild sunflower and gabi (*Colocasia*). There were also tall bamboos, and several fruit trees such as banana (*Musa*), jackfruit (*Artocarpus*), and mango (*Mangifera*).

In Barangay Brookside, the two backyard farms were separated by a stream and situated within an open area of about 0.001 km^2. Tall grasses (*Miscanthus* and *Cenchrus*) bordered each bank of the stream. A smaller garden was immediately adjacent to the residential area and was regularly planted with vegetables such as lettuce and cabbage. Most of the plants that were planted were

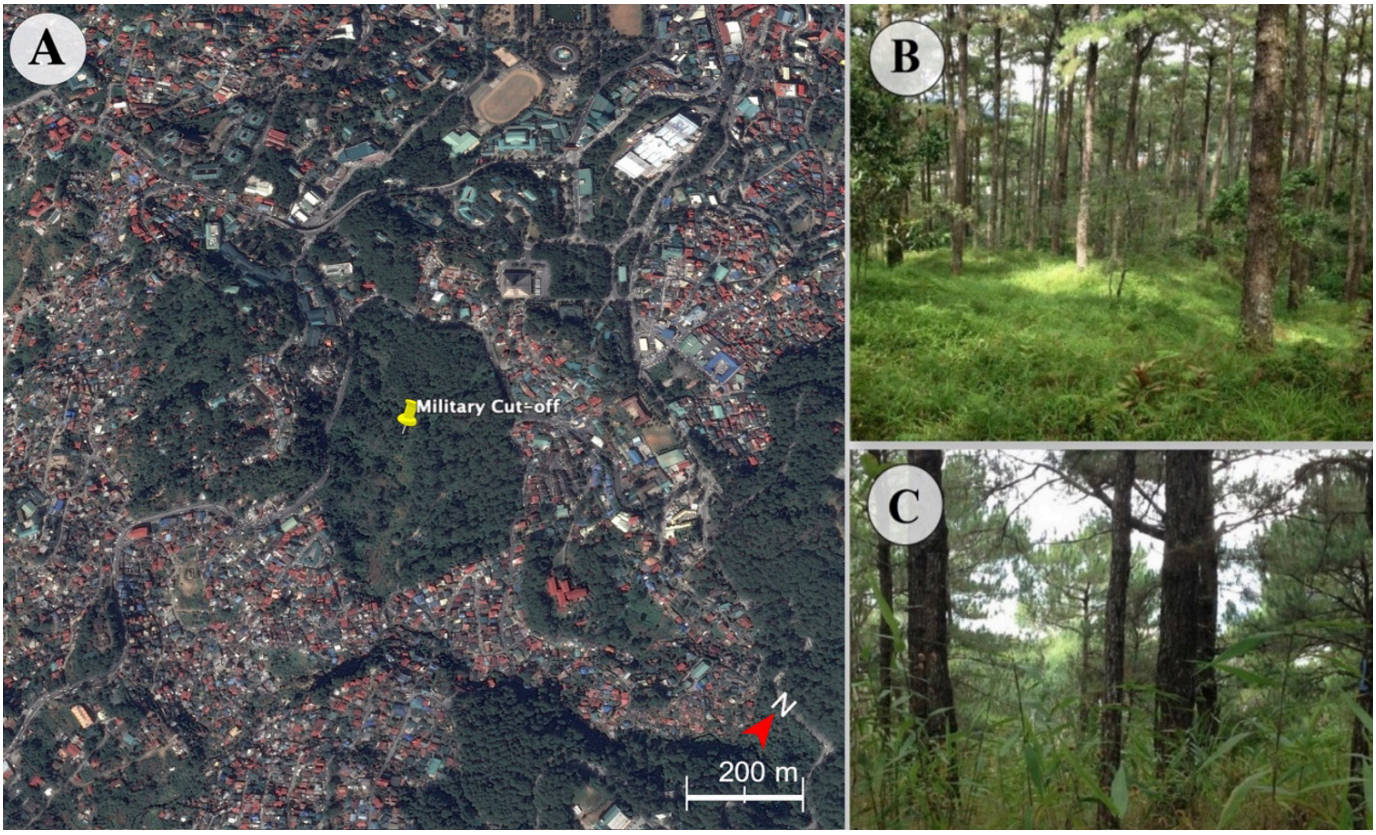

Figure 2. A satellite image of one of the forest fragment surveyed (A) and photographs of pine stands (B & C) (Map data: Google, DigitalGlobe. Accessed: December 2014).

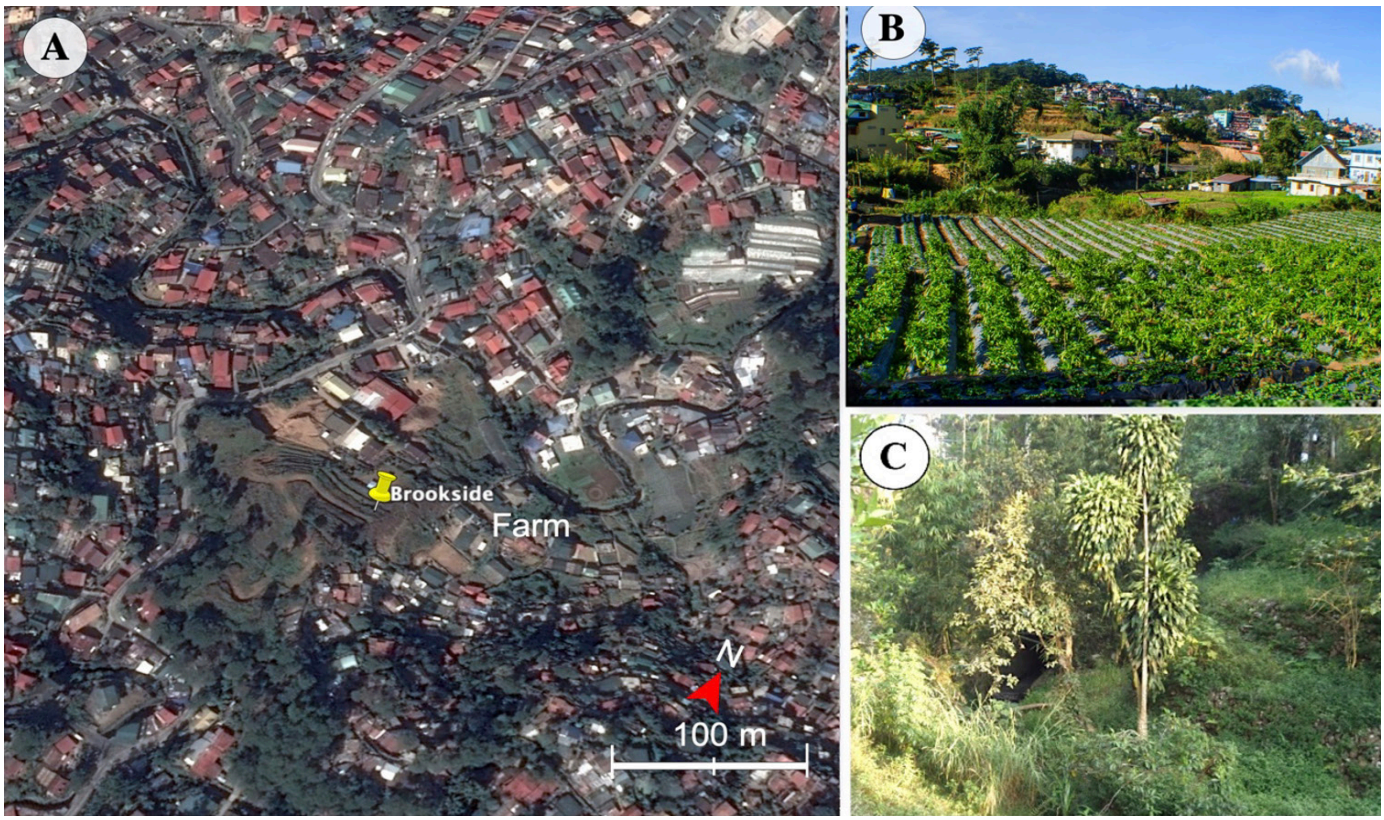

Figure 3. A satellite image map showing the location of one of the backyard farms (A) and photographs of two backyard farms (B & C) (Image B is a photo by John Edward Felipe; Map data: Google, DigitalGlobe. Accessed: December 2014).

strawberries and bell pepper. Unlike the smaller garden, the other garden was situated on the side of the steep hill and tall grasses grew along the edges of the garden.

For the farms in Loakan, the flower gardens were beside an airport (Loakan Airport). One garden, about 0.007 km^2, was planted with flowers and the other with a mix of vegetable, strawberries, and ornamental plants (e.g., *Anthurium*) (**Figure 4**). This small flower farm was situated in an open area adjacent to a pine stand that bordered a section of the Philippine Military Academy (PMA). This garden was separated from the other by the airport runway, concrete fence, and a road. A household that rented the place for cultivating flowers maintained the farm. Other farms and the residential area were evidently extensive during the survey. Several local vegetables, like bitter gourd (*Mamordica*) and eggplant (*Solanum*), had also been planted. The other farm, with an estimated area of 0.002 km^2, was bordered by an extensive residential area on one side and an open grassland area on the other. Concrete fences had been constructed between the houses and farm, with holes for water drainage. Tall (e.g., *Miscanthus*) and smaller species of grasses (*Themeda* and *Paspalum*) dominatedthe open area, which according to the locals, was also utilized as pastureland for cattle. Strawberries, cabbage, and broccoli were mostly cultivated here.

Residential Areas and Public Market. Two types of highly urbanized areas of Baguio City were sampled-residential areas and the public market. The population in many residential areas of Baguio City, including areas that were sampled, mainly consisted of local residents and students that came from nearby provinces. Houses were built extensively even in steep areas (**Figure 4**). Concrete roads, narrow streets and staircases traversed many of the steep areas. Despite street canals covered with concrete, some residents created holes to drain waste water. It was observed that the holes served as passageways of rats from canals to the houses.

Two areas, Barangay Irisan and Barangay Ambiong, were selected (**Figure 1**). The residential area in Barangay Ambiong, about 0.005 km^2 in area, lies in a hill and surrounds the Busol Watershed. This barangay have the highest population among the barangays of Baguio City. The residential areas in Barangay Irisan, with an area of around 1.50 km^2, were mainly built along steep slopes. The dumpsite for most of the trash and waste of Baguio is located in this barangay.

The Baguio City Market, of about 0.100 km^2 in area, is located in a hill that lies at the heart of the city. Large section of the hill was levelled and occupied by major sections of the market, including the vegetable and meat

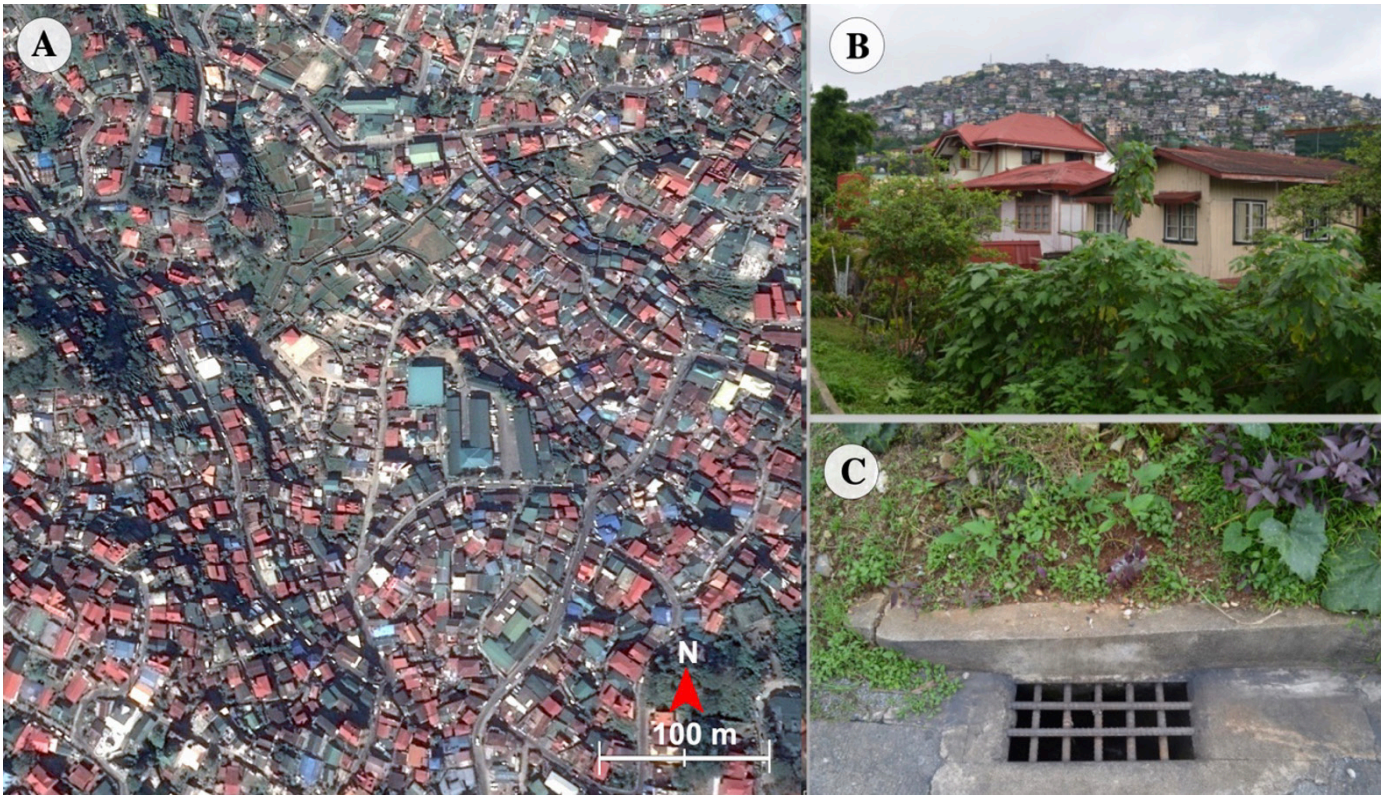

Figure 4. A satellite image map of a portion of the central business district (A) and photographs (B & C) of a typical residential area (Map data: Google, DigitalGlobe. Accessed: December 2014).

section, where sampling were undertaken. Activities in the market usually start at 4:00 a.m. and end at 11:00 p.m. A high volume of Baguio residents and tourists visited the market every day. Most commodities, including processed meat, were left in the stores of vendors. The entire area was completely paved but with visible holes in many of the canals, which drain waste water used in the wet market, and according to vendors were passageways of rats. Rats were reported to often feed fruits and vegetables sold in the market.

Trapping Procedures and Identification of Mammals

The trapping period in the pine stands, urban areas (residential areas and public market) and agricultural areas were conducted in 2012, 2013 and 2014, respectively. To minimize the possible effect of time difference as a variable in the analysis of small mammal abundance, trapping at each period was only done during the dry seasons (between January to March). The populations of small mammals, especially the non-natives, are known to be affected by fluctuations in the availability and abundance of food. In the habitats that were sampled, there were no indications of any major changes in land use or other disturbance factors (e.g., change in the landscape or change in type of crop planted; rat eradication program) was implemented during the 3-year course of the sampling. Thus, the authors believe that these variables did not affect the analyses.

In all the survey periods, standard procedure of baiting and setting of traps, which were done twice a day (one in the afternoon and another in the following morning), was followed. Correspondingly, traps were also checked in the morning and in the afternoon. All traps were set on the ground and were strategically placed in areas where small mammal activities, tracts, or passageways were evident. For each locality, traps were maintained for at least three days in a certain place before moving to another. The duration of trapping at each locality varied from five to seven days because of differences in area of the habitats that were sampled.

Snap traps and cage traps, in various combinations, were used in all sites except in the urban areas, where snap traps were mostly used because cage traps were often stolen. While this variable may seem to have an effect on the results, the authors believed that it is only minimal. In previous studies, it was found that each type of trap is effective in capturing small mammals. At each locality, the number of traps set in a day of trapping varied from 60 to 100 traps.

The number of trap lines (and number of traps per trap line) per locality varied because of differences in the characteristics of habitats that were sampled. Several traps were stolen in two of the sites, in the residential area and public market. The trapping effort in the pine stands are relatively higher, two to four times, than in the other habitat types because such habitats were much wider t. These variations produced a sampling effort for each habitat type (pine stand, backyard farm, residential area, public market) that ranged from 500 trap nights to 2,000 trap nights. Based on the analysis of trapping effort in each habitat type, species accumulation curves plateaued early on during each survey- day 4 of 15 in pine stands, day 6 of 12 in backyard farms, and day 2 of 5 days in both of the the residential areas and public market. These suggest that in each habitat type, adequate sampling were employed to detect all possible species.

The mainly used bait was roasted coconut coated with peanut butter (95-98%), known to catch both native and non-native species of small mammals that had been previously recorded in Baguio City. In the pine stands, some traps were also baited with earthworms (2%)-baits that are found to be also attractive to some species, specially native small mammals. Camote tuber (*Ipomoea batatas*) (5%) was also occasionally used for trapping in the backyard farms. Meat and fish (5%) were used in the urban areas. All these baits are known to be effective for catching non-native species.

During the survey in the backyard farms, some traps were placed inside of three houses to check the tendency of small mammals to enter houses and document the presence of the house mouse (*Mus musculus*), a species that has not been formally reported in Baguio, but was usually mentioned by local residents to be common inside their houses.

Body measurements of all captured animals were recorded and compared against the descriptions in *Heaney et al.* (*2016*) to confirm the identifications of the species. Idendification was verified by by Dr. Lawrence Heaney and Mr. Danilo S. Balete, experts in small mammal systematics and staff at the Field Museum of Natural History in Chicago, Illinois. All captured animals were prepared as voucher specimens and were kept at the University of the Philippines Biology Laboratory in Baguio.

Data Analysis

Patterns of proportional abundance of individual species was used to determine the degree of the use of

habitats and extent of occurrence of the small mammals. A Chi-square test (*Rickart et al. 2007*) was used to assess this. To address differences in sampling effort in each habitat type, expected values were computed based on the trapping effort (per 100 trap nights) and the total number of captured individuals. It was assumed that tthe distribution of species across the four habitats were even. While this study acknowledged that the differences in the sampling period of the different habitats may affect the relative abundance of the small mammals, the authors predicted that it was minimal because each of the three surveys were done during the same season. It was assumed that the dynamics in the population of the small mammals remain stable in the absence of any strong factor (e.g., change in the availability of food, forest fire, building construction)- no such factors were encountered during the three-year sampling period. To support the analysis, the authors also presented qualitative descriptions of the vegetation and physical characteristics of the habitats as well as information on the specific sites where a species was captured. Because *M. musculus* does not occur outside of buildings, and the effort to document this species was limited, data for this species were not included in the statistical analysis of patterns of proportional abundance and its occurrence in the area was only reported. The notes on the frequency of capture across the thirteen localities supported the analysis.

RESULTS AND DISCUSSION

The global expansion of urban areas is accompanied by conversion of forest habitats, creation of mosaics of habitats, and the invasion and proliferation of commensal species. Invasion of species, which is exacerbated by habitat disturbance, poses a threat to native faunas (*Sax et al. 2005*). Several studies have shown that invasion of commensal species leads to severe reduction in number and extinction of some organisms (*Atkinson 1985; Jones et al. 2008*), including small mammals (*Harris 2009; Hanna and Cardillo 2013*). In the Philippines, with over 100 million people (*PSA 2021*), and with exceptionally high levels of endemism among many groups of organisms, including mammals, these issues may have especially great importance (*Rickart et al. 2011b; Ong and Rickart 2008; Ong et al. 1999; Heaney and Regalado 1998*). The most obvious consequence of urbanization is the fragmentation of natural environment into patches of varying size and quality (*Dickman and Doncaster 1987*). The remnant patches provide habitats for a range of mammal species *(Baker and Harrison 2007*) as well as some other organisms including a wide range of vertebrates (*Ong et al. 1999*). The prevalence of mammals in remnant patches of semi-natural habitats and other different habitats in urban places is dependent on their ability to survive and reproduce and the patterns of human tolerance and conflict (*Baker and Harris 2007*). These trends were also observed in the environment studied here.

The total accumulated trap-nights of 4,711 yielded 94 individuals of small non-flying mammals (**Table 1**). All the species obtained were non-natives, including three murid rodents (*Rattus exulans, R. tanezumi and Mus musculus*) and one shrew (*Suncus murinus*).

The four habitats sampled primarily varied in two aspects: vegetation structure and the degree of anthropogenic disturbances (**Table 2**). The pine stands were composed of trees, and thick understory vegetation that was mainly composed of grasses (e.g., *Themeda, Paspalum, Miscanthus*), ferns (*Pteridium aquilinum*) and other weeds (e.g., *Ayapana, Ageratina, Alternanthera* and *Drymaria*). Minimal disturbances characterize these habitats. The backyard farms showed intermediate characteristics. Plants thickly cover the periphery of the

Table General occurrence and comparison of relative abundances of non-native small mammals among various habitat types in Baguio City, Benguet Province.

Species	Common name	Habitat				Total	X^2	P
		Pine Stands	Backyard Farms	Residential Area	Public Market			
Rattus exulans	Polynesian rat	4	**7**	0	0	11	9.75514	<0.025
Rattus tanezumi	Oriental house rat	9	**22**	13	23	67	50.2244	<0.0005
Suncus murinus	Asian house shrew	7	**9**	0	0	16	10.9077	<0.02
Total captures		20	**38**	13	23	94	37.2767	<0.0005
No. of trap-nights		2000	1211	1000	500			
Trap success (%)		1.0	3.1	1.3	4.6			
Level of Human Activity		minimal	low	high	very high			

Notes: For every species observed, abundances were compared to expected values that were based on trapping effort and total number of captured animals. Chi-square values and probabilities are shown in the last two columns. Values that are greater than what is expected are in bold.

Table 2. Qualitative differences of the four habitat types and occurrence of small mammals in Baguio City, Benguet Province.

Habitat types	General Characteristics			Source/form of disturbances	Small mammal present
	Area (km^2)	Vegetation Structure	Physical Features		
Pine Stands	0.07-0.320	Predominantly composed of Benguet Pine (*Pinus kesiya*) with understory species dominated by several species of grass (*Themeda*), weeds (*Ayapana*), and fern (*Pteridium*). Other weeds, such as *Tithonia diversifolia* and *Lantana camara*, and a species of ornamental plant (*Cordyline fruticosa*), were also in some sites. Pine trees were mostly old with trunk diameters (DBH) ranging from 30-50 cm. *Alnus* and *Calliandra* were also common.	All sites, except for one (Loakan) were fragments that lie on a hill. Only one site (Buyog watershed) had a steep slope of about 45 degrees. All the others had easy slopes. All sites were bordered by residential areas.	Tree planting activities, deweeding in some areas, established trails	*Rattus exulans* *Rattus tanezumi* *Suncus murinus*
Backyard Farms	<0.01	Most of the sites were regularly planted with vegetables (e.g., beans, cabbage, broccoli, bell pepper). One site was planted with economically growing plants (e.g., banana, jackfruit, mango, coffee), and the other, with flowering plants (e.g., *Anthurium*) Weeds (e.g., C*enchrus, Ayapana, Tithonia*) commonly occupied uncultivated areas and on banks of stream.	All farms were bordered and immediately adjacent to residential areas. Small streams were present in two of the sites (S. Sanitary Camp and Brookside). Most farms lie on a levelled land while one farm was a terrace on the bank of a small stream (S. Sanitary Camp).	Gardening by farmers	*Rattus exulans* *Rattus tanezumi* *Suncus murinus*
Residential Areas	0.05-1.50	In the residential areas weeds commonly occupy vacant lots and on edges of some streets.	In the residential areas, houses were extensively built on hills. Roads and streets were paved. Street canals were covered but some drained the waterways of adjacent houses.	Usual daily human activities Moving vehicles	*Rattus tanezumi* *Mus musculus*
Public Market	1.00	Plants were confined in flower boxes.	Public market mostly lie on a levelled area of a hill at the heart of the city. The entire area was paved. Canals were covered but with evident passages of small mammals.	Unusually high level human activities High volume of garbage was generated.	*Rattus tanezumi*

gardens and along banks of streams, whereas the level of disturbance is relatively higher than in pine stands (**Table 2**). The residential areas and the public market had the highest level of disturbances and the absence of vegetation was a shared characteristic (**Table 2**). The level of disturbance, however, was relatively higher in the public market than in the residential areas. One notable characteristics of the public market was the daily

generation of a high volume of garbage that included wastes known to attract non-native small mammals.

The results of this study provided a better understanding of the habitat use and occurrence of non-native small mammals in Baguio City, the largest of the Philippine cities in an upland area and where fragments of forests remain. The long history of human use of this area of the Central Cordillera- from pasture land (*Reed 1976*) to the formation of several types of habitats at the present time- strongly affected how these species of mammals inhabit the area. Many of the pasturelands have been developed for residential or commercial use. The protection of forest reserves and watersheds that allowed the proliferation growth of pine trees, as well as the various human activities, created a complex ecosystem in an upland urban-forest setting that are used variably by small non-volant mammals. Two species, the rodents *R. tanezumi* and *R. exulans*, are pests (*Ong and Rickart 2008*) that can potentially cause agricultural losses and serve as reservoir for parasites and pathogens that may be pass on to humans (*Eduardo et al. 2008*).

Across the habitats, only in pine stands and backyard farms were all four species found (**Tables 1** and **2**). The relative abundance of the three species (*R. exulans, R. tanezumi* and *S. murinus*) differed significantly (X^2=141.8; df=6; P<0.0005) (**Table 1**). There were 3-4.5 times more small mammals in the backyard farms and public market than in other habitats (**Table 1**). The difference in the use of habitat and extent of occurrence of the three species in the urban-forest setting of Baguio City appeared to have been affected generally by the differences in the structure of vegetation and level of disturbances in each habitat type. While the difference in the sampling time may also have an effect on the results, especially on relative abundance, as conditions may have been different, the authors believe that it was minimal. Also, it is unlikely that the data on occurrence was significantly affected by such time differences because the non-native species of small mammals tend to be widely distributed and tolerant to disturbances (*Heaney et al. 1998*). Although, studies in the future that address the difference in sampling time as another variable will be helpful to verify the data presented here.

This study showed that the presence and characteristic of vegetation and level of disturbance are two factors strongly associated with the difference in the occurrence and abundance of the different species. Recent reports also show that these two factors not only affect non-native species but also native species (*Reginaldo and Ong 2020*) Plant cover was the dominant feature of the pine stands and backyard farms, and small mammal population in these habitats were higher than in the other habitats. The data also strongly suggested that backyard farms are important habitat for the small mammals; these farms apparently favors the existence and thriving of all three non-native the species (**Table 1**). The degree of disturbance, mainly caused by humans, is relatively lower in these two habitats than in the residential areas. It is known that the spatial distribution of different habitats and structures significantly affect the spatial distribution of mammals in a particular area (*Harris 1981*). Several studies in Luzon island showed similar patterns of abundance (*Reginaldo and Ong 2020; Rickart et al. 2011b*).

Like in other reports (*Ong et al, 1999; Rickart et al. 2007*), the different species vary in their response to difference in the conditions of the habitats. Only *R. tanezumi* was found across all habitat types (**Table 1**), and it was the most frequently captured species (**Table 3**). It should be noted, however, that while this species generally occurs in the pine stands, it was absent in two such areas (**Table 3**). The relative abundance for this species in backyard farms and in the public market was significantly higher than expected (X^2=50.22; P<0.0005) (**Table 1**). Moreover, only *R. tanezumi* was documented in the residential areas and the public market. (**Tables 1** and **3**).

The abundance, occurrence, and distribution of *R. tanezumi* across the habitats in Baguio City supports the general pattern of use of habitat by this species. In areas with a mosaic of habitats, it is speculated that *R. tanezumi* tend to be restricted in the most disturbed habitats (residential area) and occassionaly wander to nearby habitats such as pine sands (*Reginaldo and Ong 2020*). A study in forested areas in Metro Manila, Philippines, reported the same tendency of this species relative to *R. exulans*- it is generally more abundant and widespread than *R. exulans* (*Ong et al. 1999*). The relatively higher number of individuals in the public market and backyard farms than in the other habitats confirms previous findings that this species is abundant in urban and agricultural areas (*Stuart et al. 2008*), as well as in complex agro-ecosystems where villages, rice fields, and nearby cane lands are present (*Miller et al. 2008; Stuart et al. 2007*) or more specifically, this commensal species occur in areas where human activities are high (*Heaney et al. 2016, 1998*). Notably, the number of *R. tanezumi* in the residential area is lower than in the market and backyard farms (**Table 1**). The authors believe that this does not imply that *R. tanezumi* are not common in this type of habitat.

Table 3. Occurrence of the non-native species of small mammal among the different localities in Baguio City, Benguet Province.

Species	Pine Stands				Backyard Farms						Urban Area		
	Camp John Hay	Military Cut-Off	Buyog Water shed	Busol Water shed	South Sanitary Camp		Brookside		Loakan		Market	Residential Area I (Ambiong)	Residential Area II (Irisan)
					I	II	I	II	I	II			
Rattus exulans	×	×	√	×	√	×	√	×	×	×	×	×	×
Rattus tanezumi	√	×	√	×	√	√	√	√	×	√	√	√	√
Suncus murinus	√	√	×	√	√	√	×	×	√	√	×	×	×

Many studies have already shown that *R. tanezumi* is abundant in urban areas. Backyard farms, in addition to the residential and market places, served as favorable habitat for this species (**Table 1**). Burrows of *R. tanezumi* were also found in such areas, an indication that *R. tanezumi* builds its nests there.

In Banaue, a rice-growing community in the Cordillera, the ability of *R. tanezumi* to also utilize adjacent habitats other than agricultural areas (*Stuart et al. 2007*) indicates their tolerance to varying degrees of habitat disturbances and suggest that it has a wide range of habitat use. Other studies have also reported that *R. tanezumi* had lower abundance than *R. exulans* in forests beside agricultural areas (*Rickart et al. 2011a; Heaney et al. 2005*). It is observed here, that no individual was caught in the backyard farms that were cultivated with flowers rather than vegetables. This supports the observation that the abundance and occurrence of *R. tanezumi* are also affected by the availability of food (*Stuart et al. 2007*) and that it prefers high-energy foods like rice (*Alfonso et al. 1985*), something that ornamental plants do not provide.

For *R. exulans*, this species was found in only one of the four pine-stand areas and in only two of the six backyard farms (**Table 3**). The relative abundance for this species was higher than expected in backyard farms only (X^2=9.75; P<0.025). Five of the seven individuals were trapped in the fallow garden where shrubs and weeds covered almost the whole area and only a few trees were present. The other individuals were trapped in an active farm where tall grasses and shrubs surrounded the farm. In these two areas, a polluted stream was also present (**Table 2** and **Figure 3**). The findings strongly support previous observations that *R. exulans* responses to different habitat conditions vary (*Ong et al. 1999*). Consistent with these observations, the authors found this species to be less abundant than *R. tanezumi*. In contrast to *R. tanezumi*, the habitat use by *R. exulans* cannot be generalized. While it was observed that this species was generally found in pine stands and backyard farms (**Table 1**), notes (**Table 3)** for each of the sampling sites indicate that *R. exulans* utilized sites that were dominated by a thick cover of weeds like *Tithonia diversifolia*, tall grasses and other small creeping plants like species of *Amaranthus* (**Figures 3 B** and **C**). The same observation, that *R. exulans* prefer high proportion of ground cover was consistently documented in several studies including urban areas (*Ong et al. 1999*) and other habitats (*Harper 2006; Storer 1962*). Several studies in the central Cordillera also report that this species prefer early stages of plant succession, a stage dominated by grass and forbs (*Rickart et al. 2016*). A possible reason for this preference of *R. exulans* to dense vegetation was thought to have brought about by the effect of the amount of cover in relation to the risk of predation (*Bramley 2014; Schooley et al. 1996*). The density of vegetation at particular height of the ground was found as a stronger predictor of densities of small mammals in urban habitats than habitat modification and urban disturbance (*Dickman and Doncaster 1987*). Another explanation is the possible limitation of its local distribution by competition with *R. tanezumi* (*Barbehenn et al. 1973*). Results of another study suggests that when competitors are absent, *R. exulans* tends to reach higher densities than their conspecifics (*Harper and Bunbury 2015; Reginaldo and de Guia 2014*). These various observations call for more researches in the future.

Like *R. exulans*, *S. murinus* was documented only in pine stands and in backyard farms (**Table 2**), with relative abundance higher than expected in both habitats (X^2=10.91; P<0.02) (**Table 1**) than in the other two habitats. In contrast, *S. murinus* occurred more frequently than *R. exulans*. Our results suggest that *S. murinus* is more widely distributed than *R. exulans* and is generally less abundant than *R. tanezumi*, supporting recent and earlier findings about the ecology of this species in disturbed landscapes in the central Cordillera (*Reginaldo and Ong 2020; Reginaldo et al. 2013*). Local residents often reported encounter this species

in their houses, a place where this study have not extensively surveyed. During the fieldwork in backyard farms, a cat (*Felis catus*) twice brought individuals of this species into the house where one of the authors was staying. These suggest that *S. murinus* is widespread and abundant in disturbed areas, supporting earlier reports that it is abundant and widespread in urban areas (*Rabor 1986; Ong et al. 1999*), including inside of buildings (*Esselstyn 2004*). Studies elsewhere report specific preference of shrew in urban setting or in mixed-use urban setting: areas with moist condition, including montane forest patches adjacent to agricultural areas (*Reginaldo et al. 2013*)

This study also reported the presence and comment on the occurrence of *M. musculus*. Two individuals were captured in one of the four houses that was sampled and none was documented in any of the habitats. This species was previously reported to be common in human habitations in urban areas at low elevations (*Heaney et al. 1998*). The results indicate that it may be restricted to houses and other buildings. This species is commonly reported by residents, suggesting that it may also be widespread in Baguio City.

This study also noted that none of the previously recorded native species *Apomys musculus*, *Bullimus luzonicus*, and *Rattus everetti*, caught in a different section (about a kilometer away from the study site) of the forest fragment in *Reginaldo et al.* (*2013*), were found in any of the pine stands that we surveyed, including the locality that is part of the Camp John Hay Forest Reserve. It was speculated that the characteristic of the understory vegetation plays a role in the presence of native species (*Reginaldo et al. 2013*). Recent studies supported the suggestion, stating specifically that the presence of remnant, broad-leafed montane forest along gullies and stream banks harbor native species. The section of the forest fragment where the native species were recorded in other studies primarily differ in three aspects: the structure and condition of the understory vegetation and the level of disturbance. These observations suggested clues on the limit of conditions that allow the survival of native species and more thorough studies in the future will help elucidate the extent at which native tolerate disturbance and persist in disturbed landscapes. The authors suspected that native species were present in pine stands, and their inferred absence was due to the limited methodology that specifically target native species. Also, there is the lack of prior knowledge about the specific places noted by other studies to harbor native species. These findings call for serious attention to the protection of forest reserves such as the the Camp John Hay Forest Reserve because these are a biodiversity refuge. Studies suggest that human activities ushered the spread non-native species, and pest species are confined within and around disturbed habitats (*Reginaldo and Ong 2020*). If this is the case, keeping a forest reserve in good condition may serve two things: allows the native species to thrive and keep the population of non-native species low.

CONCLUSIONS AND RECOMMENDATIONS

The sampling of four different habitats in an upland urban-forest setting resulted to the capture of four of the seven previously documented small mammals in Baguio City, all being non-native species, namely, *Rattus tanezumi*, *R. exulans*, *Suncus murinus*, and *Mus musculus*. The record of *M. musculus* is first formally reported in this study. This study showed that absence or presence of defined vegetation as well as differences in the degree of human disturbances in each habitat are good predictor of the difference in the occurrence and distribution of non-native, small, non-flying mammals.

It is clear that the three abundant species, *R. tanezumi*, *R. exulans*, and *S. murinus*, vary in their responses to condition of habitats. *Rattus tanezumi* has stronger association with the presence of humans, occurring abundantly in all areas of the city, except in pine forests. *Rattus exulans* is restricted to pine stands and backyard farms, habitats thickly covered with vegetation. *Suncus murinus* is widespread but is less abundant than *R. tanezumi* and probably occurring in all habitats including houses and buildings. Many ecological factors are thought to affect the use of habitats by different species of small mammals. Some generally works consistently across various types of habitat while others are localized. The absence of native species in the pine stands suggest for clues on the possible factors that limit their existence. Based on the findings and from previous works, differences in the structure and condition of pine stands appear to play an important role. In the future, researches that identify specific habitat variables that may affect habitat use can help to further elucidate the findings of the study. The study provides important information about the ecology of non-native species that includes pest species. The results, observation, and insights that the authors provided here are helpful in formulating management plans to control the population of pest species. Control of population may not always need killing of animals, but maintaining good quality of habitats that potentially support native species. Because this study mapped out the possible distribution of pest species, targeted control may be done to reduce therisk of acquiring pathogens known to be caried by pest species.

The authors predicted, based on the generality of the results and reports from other studies, that the patterns of occurrence and distribution this study elucidated were also true in other places in the country that shared characteristics with this study localities.

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