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DISTRIBUTION OF NATIVE AND NON-NATIVE RATS (*RATTUS* SPP.) ALONG AN ELEVATIONAL GRADIENT IN A TROPICAL RAINFOREST OF SOUTHERN LUZON, PHILIPPINES

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Abstract. Rats (Muridae) of the genus *Rattus* occur in the Philippines, both as native and as invasive species. While the invasive species are well known to use a large range of anthropogenic habitats, little is known about their potential to occur in forest areas. We studied the occurrence and relative abundance of different species of *Rattus* in forests along elevational gradients on three mountains within the Palay-palay / Mataas na Gulod National Park in Southern Luzon, Philippines. Four *Rattus* species were collected and their occurrence and relative abundance were found to differ significantly between species and along elevational gradients. *Rattus norvegicus* (40.3% of captures), *R. tanezumi* (21.5%), and *R. argentiventer* (5.6%) are invasive species and *R. everetti* (32.7%) a native forest-inhabiting species. While the three invasive species were most abundant at low elevations, *R. everetti* was most abundant at higher elevations. The number of invasive rats has been attributed to their survival and adaptation at lower elevations, where habitat conversion and degradation are most intense, while native species are more common at higher elevations where habitat is relatively undisturbed.

Key words: *elevation*, *forest species*, *invasive species*, *Philippines*, *rainforest*, Rattus *species*.

INTRODUCTION

Rats (Muridae) use different habitats in tropical forests in variable abundance, and species may differ in their ability to utilize different lowland, montane, or mossy forests (Mallari & Jensen 1993, Heaney *et al*. 1998, Tabaranza *et al*. 2002). Many lowland species assemblages are known to include native as well as invasive species (Rickart 1993). The Philippines are known for their diverse mammal fauna, including at least 172 native and seven introduced non-native terrestrial species. Philippine mammal assemblages are characterized by an exceptionally high endemism of around 60% (Heaney *et al*. 1998). Newly discovered endemic species have been recorded recently either on relatively small islands or in the high mountain ranges of Luzon and Mindanao islands (Sinha & Heaney 2006).

The murid rats, comprising 22 genera and 56 species native to the Philippines, are the most speciose and most diverse in terms of morphology and ecology. They comprise an important faunal element and occur at high abundances in local mammal assemblages (Heaney *et al*. 1998, Steppan *et al*. 2003). Most of the murid rodents occurring in higher elevation habitats are endemic species. Many forest rodents are well adapted to pristine habitats, and forest destruction threatens the long-term survival of these species (Heaney & Regalado 1998, Heaney *et al*. 1999, Tabaranza *et al*. 2002). It is assumed that the invasion of exotic rat species in the Philippine forest poses threats to the endemic species because invasive species affect their biological communities through competition or predation, resulting in possible extinction of native species (Heaney 1995). In addition, the status of both endemic and invasive rodents is an excellent indicator of forest conditions, since endemic mammals can be among the most threatened species when conditions become unfavorable (Goodman 1995), while the presence of large populations of invasive species in the forest is indicative of an ecological imbalance within the habitat (Lehtonen *et al*. 2001).

Mounts Palay-palay/Mataas na Gulod (MPMNG) lies in the provinces of Cavite and Batangas, Southern Luzon, Philippines. It was established as a National Park in October 1976 (DENR 1992). The park is

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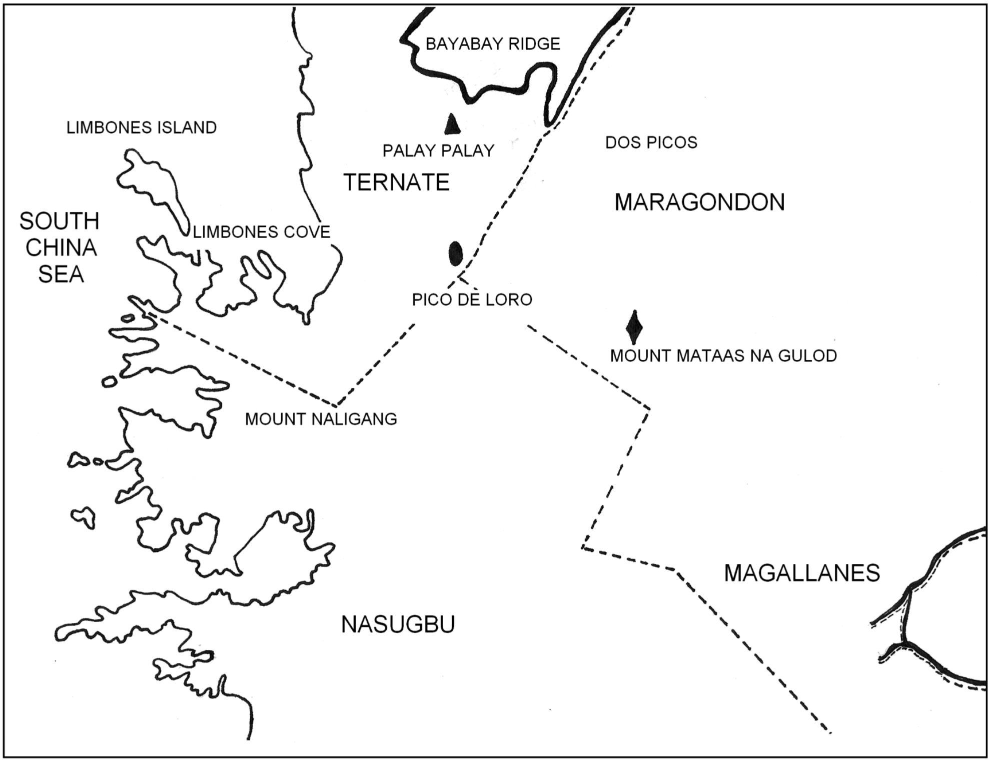

FIG. 1. Map of Mts. Palay-palay / Mataas na Gulod National Park showing the three peaks: Palay-palay at 595 m a.s.l. ▲, Pico de Loro at 648 m ⬮, and Mataas na Gulod at 622 m ♦ (NAMRIA 1993).

one of the few remaining low-elevation tropical rainforests in the Philippines. The park is composed of approximately 62.5% forest and 37.5% non-forest vegetation and the main tree families include Verbenaceae (molave) and Dipterocarpaceae.

We studied the rodent species of the forest in order to contribute to the conservation efforts of MPMNG National Park. In this study, we surveyed the occurrence and distribution of *Rattus* species in the wild in order to determine their diversity and to establish the occurrence of native and invasive species along an elevational gradient in relation to the type of habitat. Further, our study focused on the abundance and distribution of endemic and invasive rodents in the disturbed and undisturbed areas of the forest. The availability of such data, particularly of threatened, exploited, and exotic species, is essential for developing successful wildlife management strategies.

METHODS

Study Site. Mts. Palay-palay / Mataas na Gulod National Park is a 4000-ha mountain range at 14°12'–14°17'N, 120°38'–120°42'E, approximately 60 km southeast of the capital Manila (DENR 1992). The range includes three main peaks: Palaypalay, with an elevation of 595 m above sea level, Mataas na Gulod at 622 m a.s.l., and Pico de Loro, the highest peak at 648 m a.s.l. (Fig. 1). Its topography ranges from rolling to moderately steep and steep terrain, and soils are composed of mountain sand with clay loam. Average air humidity is 57% and temperature range is 19–28°C.

Our forest trapping sites at low and middle elevations were mostly dominated by endemic dipterocarp trees with an average height of 10 to 12 m. The forest floor is covered with aroids, grasses, and low herbs with mixed dry and wet leaves as forest litter.

While a larger proportion of the park is still covered with trees, some areas up to 400 m a.s.l. have been converted to agricultural areas and croplands. Human utilization is concentrated in the low and middle elevations. Both the lower and middle elevations are adjacent to trails and well-defined roads, that provide easy access to the National Park.

At higher altitudes there is abundant vegetation, dominated by canopy trees, which protect the understory. The average height of trees is 8 to 9 m. The terrain becomes rocky as elevation increases and the vegetation is gradually replaced with high cogon grasses (*Imperata cylindrica*), shrubs, herbs, vines, and fern. The forest floor is covered with grasses and leaf litter.

We studied three forest habitats, one on each peak. Each habitat was divided into low elevation at 0–207 m above sea level (m a.s.l.), middle elevation (208–414 m), and high elevation (415 m and above). A total of nine collection sites (three forest habitats x three collection areas covering the different elevations) was determined using stratified random sampling with reference to the forest trail and the elevation was measured in m. Sampling points were geo-referenced using a global positioning system (GPS) receiver.

Capture and handling of rats. A 100-m transect line was used in the trapping procedure, slightly adapted from Soliman *et al*. (2001) and Heaney *et al*. (1999). Single-capture live cage-traps of 12 x 7 x 7 inches (30.5 x 17.8 x 17.8 cm) were used for trapping. Each transect line was located 15 m from the main forest trail. The transect line was further subdivided into four subplots with an approximately 25-m vertical distance trapline. In each subplot, five spring-door wire traps were deployed 5 m apart. We ran on each site 20 trap nights (= 20 traps deployed for one night) hence a total of 60 trap nights for each collection site, covering the three elevation areas per collection period. Capture of rats was carried out once every three weeks, comprising nine collection periods during the six-month period between September and February. This totaled 540 trap nights over the whole duration of the study.

Traps were baited with fruits and grilled coconut flesh before dusk and were checked in the early morning the following day. Since rats might not approach novel objects in their surroundings at the first encounter (Rubio & Sumalde 1997), traps were left in place for two to three more days when no animal was trapped within the first day. The sites with traps were marked with reflective tape to facilitate relocation for retrieval or resetting. We noted the sampling location for each trapped animal and marked it by tail-tagging prior to release. During handling of the captured rats, leather or fabric gloves were worn to minimize the chances of being bitten or scratched. Captured rats were immobilized by an improvised metal stabilizer while morphological measurements were taken.

Weight as well as head, hindfoot, and tail lengths were determined for identification of the species. Rats were identified using Sanchez *et al*. (1985), Sumangil (1990), Heaney *et al*. (1999), and Salibay & Claveria (2005). Species identification was verified at the Mammalogy Section, Zoology Division of the National Museum, Manila. Voucher specimens are deposited in the Natural History Laboratory of De La Salle University-Dasmariñas (DLSU-D). Animals were handled following the animal care guidelines of the American Society of Mammalogists (ASM-ACUC 2003) and PCARRD (1985).

RESULTS

In total, we captured 107 individuals of the four species after nine collection periods over six months. The number of rats collected per collection period ranged from three to 19 individuals. Fewer rats were caught during rainy days than on dry days. All of the four rat species caught belonged to the genus *Rattus*: *Rattus norvegicus* Berkenhout (Norway rat), *R. everetti* Gunther (common Philippine forest rat), *R. tanezumi* Temminck (Oriental / Asian house rat), and *R. argentiventer* Robinson and Kloss (ricefield rat). Among the rats collected, *R. norvegicus* was the most abundant, followed by *R. everetti*; *R. tanezumi* and *R. argentiventer* were least abundant (Table 1). The total number of rats collected varied significantly across the species ($\chi^2 = 29.03$, $p < 0.05$). Interestingly, most of the captured species (*R. norvegicus*, *R. tanezumi*, and *R. argentiventer*), were non-forest species, and are considered to be pests. Most of them were captured near human habitations and abandoned structures (*R. norvegicus* and *R. tanezumi*), or in rotten logs and agricultural areas (*R. tanezumi* and *R. argentiventer*). *Rattus everetti* was the only native Philippine forest rat species caught in this study. The main habitat of *R. everetti* is undisturbed forest.

The numbers of captured rats differed significantly between elevations ($\chi^2 = 54.95$, $p < 0.05$), with the highest number (45.8%) observed at low eleva-

TABLE 1. Number of invasive and native *Rattus* species caught over an elevational gradient in the rainforest of Mts. Palay-palay / Mataas na Gulod, southern Luzon, Philippines. There were significant differences in species abundance between the species (last column, χ^2 = 29.03, $p < 0.05$); and over the elevation gradient (last row, χ^2 = 54.95, $p < 0.05$).

Rat Species	Elevation			Total (%)
	Low	Middle	High	
R. norvegicus	28	10	5	43 (40.3)
R. tanezumi	15	8	0	23 (21.5)
R. argentiventer	6	0	0	6 (5.6)
R. everetti	0	16	19	35 (32.7)
Total (%)	49 (45.8)	34 (31.8)	24 (22.4)	107

tion (Table 1). Assemblages at low elevations were dominated by *R. norvegicus* (57.1%) and *R. tanezumi* (30.6%), while there were fewer *R. argentiventer* (12.2%) and no *R. everetti* was caught at low elevations. In contrast, *R. everetti* (47.1%) was at middle elevations, together with *R. norvegicus* (29.4%) one of the most abundant rats. Of all the rats captured in this area (31.8% of the total number), no *R. argentiventer* were observed at middle elevations. At high elevations, *R. everetti* (79.1%) dominated and only few *R. norvegicus* (20.8%) were trapped. Other species (*R. tanezumi* and *R. argentiventer*) were not observed at high elevations. Our results further showed the highest number of invasive species at lower elevations. The invasion of the protected forest by non-native species is most pronounced at lower elevations where habitat conversion and degradation are intense. On the other hand, the native species, *R. everetti*, was observed to increase in number with elevation.

While elevation affects the number of rats collected across all species, the presence of native and invasive species probably depends not directly on elevation but on the species‘ habitat preference. Hence, the predominance of invasive species increases where human habitation, camp sites, infrastructure development, logging and agricultural areas are situated, in the low and middle elevations. It was also observed that most of the *R. norvegicus* were seen approximately less than 400 m away from human habitation, the camp site, and roads and trails, regardless of the elevation. *Rattus tanezumi* was mostly observed in the same areas where *R. norvegicus* was caught, as well as in logging and agricultural areas, which were all located at lower elevations. All *R. argentiventer* were observed within the vicinity of the agricultural land area. The presence of *R. everetti* at higher elevations can be attributed to their preference for habitats with intact vegetation and relatively undisturbed forest areas, which was commonest at the higher elevation gradient. In fact, 30 (86%) of the 35 *R. everetti* were caught in the undisturbed areas of the middle and high elevations while the rest were caught near the forest trails and camp site of the middle elevation.

DISCUSSION

All the *Rattus* species that we caught at the different elevations of MPMNG forest are widely distributed in the Philippines, but only *R. everetti* is a native resident of Philippine forests. The presence of *R. everetti* has been documented mainly in forest with intact vegetation, from sea level to 2200 m a.s.l. in Luzon island (Heaney *et al.* 1999), and up to 2400 m in Mindanao. Although there were a few records of the presence of *R. everetti* in disturbed areas, it is uncommon in secondary forests and usually absent in agricultural areas (Musser & Heaney 1992, Mallari & Jensen 1993, Rickart *et al.* 1993, MFPI 2002). The preference of *R. everetti* for undisturbed forested areas has been confirmed in previous studies (Rickart *et al.* 1993, Heaney *et al.* 1999). This species thrives in dense vegetation, and its numbers increase within the more pristine areas of the forest (Rickart 1993, Heaney & Tabaranza 1995).

The other species, *R. norvegicus*, *R. tanezumi*, and *R. argentiventer* are non-forest rats and may be considered as invasive pest species. The distribution of

FIG. 2. The *Rattus* species collected in Mts. Palaypalay/Mataas na Gulod National Park, Southern Luzon, Philippines. Upper left: *Rattus norvegicus* (Norway rat), upper right: *Rattus tanezumi* (Oriental house rat), lower left: *Rattus argentiventer* (Common ricefield rat), lower right: *Rattus everetti* (Common Philippine forest rat).

these rodents in the different islands of the Philippines varies, with *R. tanezumi* dominating in Luzon and Visayas islands, and *R. argentiventer* in the islands of Mindanao and Mindoro. *Rattus norvegicus*, along with *R. exulans*, dominates on the islands of Cebu and Palawan (Fall 1977). In addition, both *R. norvegicus* and *R. tanezumi* are common and widely distributed in disturbed and urbanized habitats in the Philippines (Heaney *et al.* 1999, Salibay & Claveria 2005). *Rattus argentiventer* is widely distributed in low-elevation areas in grasslands and rice plantations throughout the Luzon, Mindanao, Mindoro, and Visayan faunal regions and is believed to be absent in the central and northern Philippines (Sanchez *et al.* 1985, Heaney *et al.* 1999, MFPI 2002).

Studies on terrestrial vertebrates in MPMNG recorded the presence of *R. tanezumi* and *R. norvegicus* at low elevation ranging within 25–100 m (Guyamin, 2005). While in this study only four *Rattus* species were collected in MPMNG, related studies recorded additional species such as *R. exulan* and *Apomys* spp. (Lope & Hernandez 2008) and *Mus musculus* (Salibay *et al.* 2006).

Rattus norvegicus lives commensally with man, in human dwellings and other buildings (Heaney *et al.* 1999, Salibay & Claveria 2005). It is also present in disturbed low-altitude forest areas and can flourish at higher elevations when forest areas are modified by developed farm tracks or establishment of agroforestry (Sanchez *et al.* 1985, Gratz 1990).

The conversion of lowland forest to agriculture may have prompted the increase in *R. tanezumi* numbers at the site, since the species is known to invade agricultural land (Fall 1980, Sumangil 1990). For native faunas, this is the most damaging invasive rodent species on islands worldwide (Hingston *et al.*

2005). In our study, *R. tanezumi* was caught mostly at lower elevation and the absence at higher elevations suggests that the species is more restricted to disturbed and agricultural areas. This observation confirms other studies (Lepiten 1995, Lehtonen *et al.* 2001, Stuart *et al.* 2007), which found that the abundance of *R. tanezumi* increased with the level of habitat disturbance, thus it was most common in disturbed and heavily logged secondary forest, farm lots, and abandoned agricultural fields. Further, the abundance of this invasive species increased with decreasing distance from forest edge and decreasing canopy cover.

Rattus argentiventer is among the most destructive rodent pest species on agricultural land across much of Southeast Asia (Singleton & Petch 1994). The presence of this species in MPMNG could be attributed to the development of agroforestry in the lowland areas. The findings of previous studies (Musser 1973, Payne *et al.* 1985, Sanchez *et al.* 1985) are in conflict with our study regarding the presence of *R. argentiventer* at low elevations, since this species feeds on agricultural crops, rice paddies, and grasslands and seldom enters high elevational areas of the forest areas unless food becomes scarce in lower areas.

Biological invasions are an omnipresent environmental and costly economic problem (Kennedy *et al.* 2002, Hingston *et al.* 2005). Ironically, most of the successful animal invaders are the ones that are – as a consequence of human actions – able to cross major barriers (Heaney and Regalado 1998, Hingston *et al.* 2005). The presence of non-forest rat species in the lower elevations of MPMNG demonstrates their ability to survive the conversion of forested areas to agricultural land and human dwellings and activities (Luyon & Salibay 2007). It has also been reported that range expansions of invasive species into natural habitats may be caused by rapid deforestation or degradation and fragmentation of the natural forests. Such changes frequently create a habitat suitable for invasive but not for most native rodent species (Goodman 1995, Lehtonen *et al.* 2001). In fact, the consequences of invasions of non-indigenous species are particularly pronounced for island communities with high proportions of endemic species.

So the presence of non-forest *Rattus* species in MPMNG suggests a poor condition of the forests areas. Human activities such as over-exploitation of natural resources, including hunting and logging, have been observed to some extent in MPMNG (Guyamin 2005, Salibay 2006). Such activities have presumably led to the introduction and propagation of non-forest rats through habitat changes that favor their survival. The unsustainable practice of upland farming is a major threat to biodiversity conservation in the Philippine forests, including MPMNG, because it results in an extensive removal of vegetation and fragmentation of the upland forest.

In conclusion, elevation does not directly influence the distribution of invasive or native species and it is rather the condition of the forest habitat (whether disturbed or pristine) which has affected the distribution of the rat species present. Hence, the indiscriminate use of the forest has resulted in habitat changes which, in turn, have facilitated species invasion. Continued human activities in the forest, i.e. agricultural landscapes dominated by rice growing and farming on the slopes, have significantly changed the vegetation. The combination of farming with some small patches of cultivated land and animal grazing, and even logging at lower elevations, has contributed to the increase of non-forest rats in the area. The presence of highly invasive species like *R. norvegicus*, *R. tanezumi*, and *R. argentiventer* may ultimately result in the extinction of endemic species, such as *R. everetti*, if anthropogenic detrimental activities in the forest continue. Monitoring and investigation of rodent species with the aim to determine occurrence and habitat utilization in undisturbed and converted habitats, and to understand other important aspects of their population ecology, need to be emphasized, since these small mammals are excellent bioindicators of forest condition.

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