

Non-volant small mammals of Pagan Island, Commonwealth of the Northern Mariana Islands

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Introduction

This work covers the small non-volant mammals of Pagan, including all rodents encountered during June and July 2010 within the land environment and/or captured via live traps and snap traps.

Little is known regarding the non-volant small mammals of Pagan. Previous observations and fieldwork on Pagan suggested the presence of two rat species on the island, one larger than the other, as is typical of most islands in the Mariana chain. One specimen of *Rattus exulans* was previously collected from Pagan by Charles Ross in 1979 (NMNH 530819). This is a small-bodied rat that may be active both day and night and which is often conspicuous during visual surveys, but interestingly, this species was not detected on Pagan during fieldwork in 1999 and 2000. Minimal snap-trapping during a CNMI DFW research trip in 2000 resulted in the capture of eight rats identified as *Rattus rattus*. Based on conversations with the biologists who conducted the fieldwork, along with inquiries to the Bishop Museum, we concluded that if specimens were collected in 2000 they are now lost or destroyed.

Perceptions of the identity of the larger rat species in the Marianas have changed markedly over the years. The species was historically considered *R. rattus*, and there are museum specimens of this species from Guam, but some recent authorities have stated that more recent specimens from Guam were *R. tanezumi*, implying that the latter had replaced *R. rattus*. More recently, genetic analyses tentatively identified specimens from the southern Marianas (Guam, Rota, Tinian, Saipan) as *R. diardii* (Wiewel et al. 2009), suggesting that *R. tanezumi* had in turn been replaced by *R. diardii* on these islands. Other small mammals are possible on Pagan. The house mouse, *M. musculus*, is present on all of the human-occupied southern islands and often accidentally transported to new islands, while *Suncus murinus* is present on some of the southern islands. Snap-trapping, live-trapping, and visual surveys are typically effective at determining presence of these species in the Marianas.

Originally, eight snap-trapping lines for rodents in various habitats and two mark-recapture grids to estimate rodent densities. However, our sampling schedule was greatly abbreviated by a volcano-related evacuation and by the decision by FWS to end biology-related operations on Pagan prior to the scheduled date for completion of our fieldwork. These changes resulted in completion of only one rodent grid, although we succeeded in sampling most major habitat types via visual and snap-trap surveys.

Table 1. Scientific and common names of species mentioned in this report with taxonomic family and general animal type.

Scientific name	Common name	Family	Animal type
<i>Mus musculus</i>	House mouse	Muridae	Nocturnal rodent
<i>Rattus cf. diardii</i>	Malayan house rat (?)	Muridae	Nocturnal rodent
<i>Rattus exulans</i>	Polynesian rat	Muridae	Diurnal/nocturnal rodent
<i>Rattus rattus</i>	Black rat	Muridae	Nocturnal rodent
<i>Rattus tanezumi</i>	Oriental house rat	Muridae	Nocturnal rodent
<i>Suncus murinus</i>	Musk shrew	Soricidae	Diurnal/nocturnal shrew

Materials and methods

We sampled small-mammal populations on Pagan with both live (1 site) and snap traps (5 sites). Small mammals were also surveyed during nocturnal visual surveys and during opportunistic diurnal visual sampling. Rodents were commonly detected at night in fruiting trees such as mango (*Mangifera indica*) and within *Cocos* forest, but no species were detected during visual searching that were not captured by traps.

Live trapping

Between 29 June and 10 July 2010, we conducted rodent mark-recapture sampling for 12 consecutive nights on an 11 × 11 grid with 12.5 m intervals between each trap station (nominal grid area = 1.56 ha). The live trapping grid was located at the northern part of the island (grid centroid: N latitude 18.13 and E longitude 145.77, average elevation: 42.5 m) in a *Casuarina* forest with a relatively open native plant understory (e.g., *Ficus prolixa*, *Neisosperma oppositifolia*, and *Triphasia trifolia*) on a trapping substrate of soil, *Casuarina* leaves, cinders, and old lava (Fig. 12). Logistical constraints (externally imposed schedule changes) precluded live trapping in other habitats.

We placed a single standard-length folding Sherman live trap (229 × 89 × 76 mm; H.B. Sherman Traps, Inc., Tallahassee, Florida) at each trap station ($n = 121$). In addition, a single Haguruma wire mesh live trap (approximately 285 × 210 × 140 mm; Standard Trading Co., Honolulu, Hawaii) was placed at every other trap station ($n = 36$); thus the Hagurumas were spaced 25 m apart in a regular grid overlaying the Sherman grid. On 26 June, we placed closed and unbaited traps on the grid, two nights prior to the beginning of live-trap sampling to provide an opportunity for rodents to acclimate to their presence. Live trapping protocols followed those used in previous studies in the Mariana Islands (Wiewel et al. 2008, Yackel Adams et al. 2011).

We placed traps on the ground and, whenever possible, positioned them to provide shelter from sun and rain. We baited traps with a mixture of peanut butter, oats, and food-grade

paraffin and supplemented this bait with coconut during the second half of trapping (trap days 7-12); supplementation became necessary because non-target species (hermit crabs, insects, etc.) removed large amounts of bait and because roughly 1/3 of prepared bait was lost to decomposition while in storage at the base camp.

We checked traps beginning at 0600–1010h each day, closing them immediately after checking so as to minimize mortality of captured animals during the heat of the day. We reopened traps daily at approximately 1600h and re-baited as necessary to ensure bait freshness. We used the method described by Nelson and Clark (1973) to account for sprung traps when calculating sampling effort.

We examined and measured captured animals to determine species, sex, age, reproductive status, mass (g), head-body length (mm), tail length (mm), right hind foot length (mm), right ear length (mm), and testes length (mm; if applicable). Captured individuals were uniquely marked in each ear with numbered metal ear tags (#1005–1, National Band and Tag Co., Newport, Kentucky; Fig 13). Recaptured animals were examined to determine tag number. All capture, handling, and marking techniques followed guidelines approved by the American Society of Mammalogists (Gannon et al., 2007) and the U.S. Geological Survey Animal Care and Use Committee (USGS Fort Collins Science Center).

Fig. 1. Representative habitat sampled in rodent live-trapping grid on northern Pagan. Sherman trap in foreground, Haguruma trap in background.

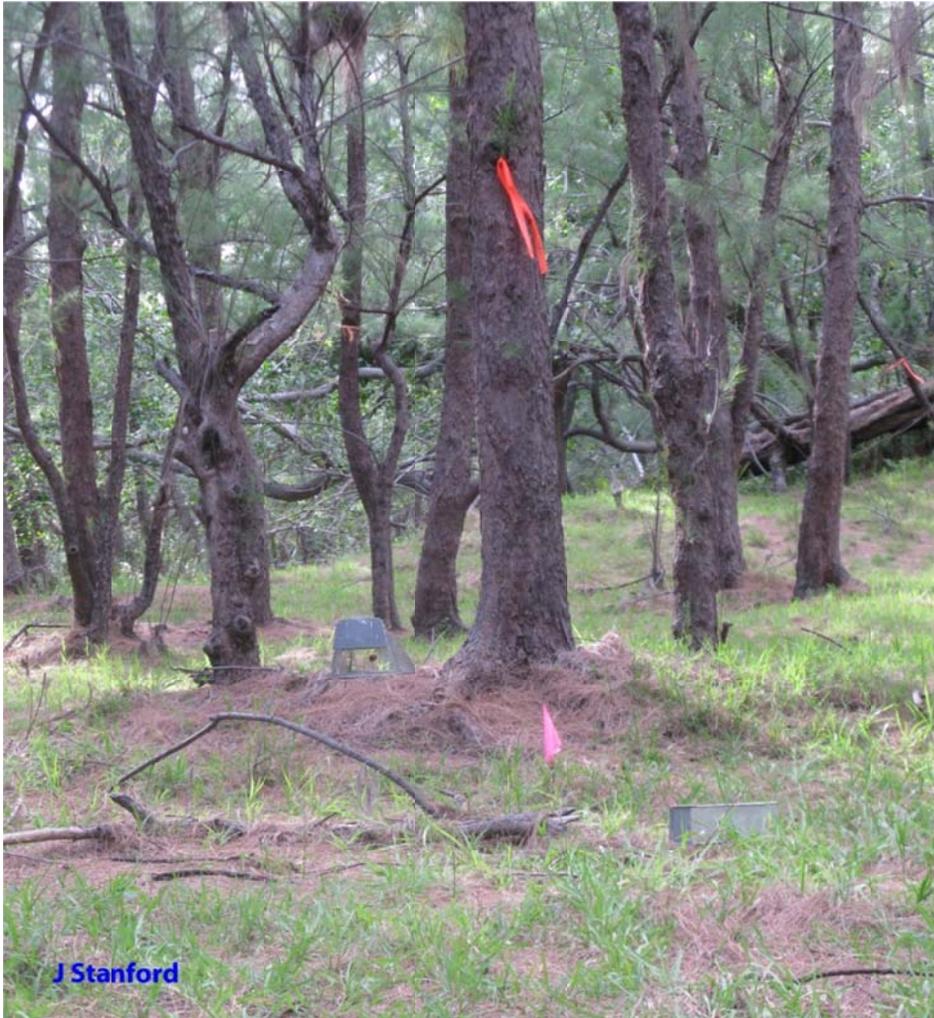


Fig. 2. A rodent (*Rattus tanezumi*) captured and newly affixed with an ear tag on the live-trapping grid on northern Pagan.



Snap trapping

Between 27 June and 07 July 2010, we conducted snap-trap sampling for 4 consecutive nights on a 1×20 linear array in each of 5 distinct habitat types. We used 3 types of snap traps to maximize captures (Victor rat traps [$175 \times 84 \times 28$ mm; Model M201, Woodstream Corporation, Lititz, PA], Museum Special traps [$141 \times 70 \times 15$ mm; Woodstream Corporation, Lititz, PA], and standard mousetraps. Victor Rat, Museum Special, and standard mouse traps were spaced at 10 m, 20 m, and 20 m intervals, respectively (40 traps total per linear array) along the same trap line. Trap placement followed placement protocols for live traps. Traps were baited with a mixture of peanut butter, oats, and food-grade paraffin and were checked between 0530 and 1000h each day. We did not bait traps during the one day acclimation period. We disposed of animals captured during snap trapping away from study sites and human-use areas.

Genetic Analysis

We collected DNA samples by pulling several guard hairs (and their associated follicles) from all captured rats. Genetic materials were stored in a dry envelope. Follicles were analyzed following the cytochrome oxidase I procedure outlined in Robins et al. (2007).

Data Analysis

Abundance estimates for live trapping were generated in Program MARK 5.1 (White and Burnham 1999) using the conditional likelihood closed capture-recapture model developed by Huggins (1989, 1991). Our analysis followed an information-theoretic approach involving model selection and multi-model inference. Model selection was based on Akaike's Information Criterion corrected for small sample size (AIC_c ; Burnham and Anderson 2002). Models were considered competitive with the top-ranked model when $\Delta AIC_c \leq 2.0$ and plausible when $\Delta AIC_c \leq 4.0$ (Burnham and Anderson 2002). To provide a robust abundance estimate, we model-averaged abundance estimates based on Akaike weights (w_i ; Burnham and Anderson 2002) based on the entire model set.

We initiated our modeling efforts by first evaluating rain amount (during the past 24 hour period [rain24] and the cumulative rainfall effects over the past 48 hour period [rain48]) because this has been an important explanatory variable for *Rattus* trap capture in this region (Wiewel et al. 2009, Yackel Adams et al. 2011). Rain amount was a quantitative measure of total rainfall (mm) measured at the trap grid center. We then evaluated a neophobia model. Our neophobia model (neo2) allowed capture probability to vary during the first and second trapping occasions while holding capture probability constant for the remaining occasions. We then added a single covariate to the best model to see if we could improve fit. Covariates with adequate information included: body-condition index, sex, reproductive status, head-body length (LNhead-body length), hind foot length, ear length, and mass (LNmass). We calculated body-condition index as the ratio between the observed and expected mass of an individual, where expected mass was determined from a linear regression of ln mass vs. ln length. We assessed covariate importance by evaluating their slope estimates and 95% confidence intervals, where covariates with 95% confidence intervals not overlapping zero were considered influential on capture probability. All estimates are presented as mean \pm 1 SE.

We calculated *Rattus* density by dividing the model-averaged abundance estimates by effective trapping area (ETA), where ETA equaled the total area encompassed by the trapping grid (1.56 ha) plus a boundary strip of half the mean maximum distance moved (MMDM) between captures for individuals captured two or more times (Wilson and Anderson 1985).

Snap trapping results were summarized by habitat. For each habitat, we estimated a catch per unit effort [CPUE; captures/100 corrected trap-nights (corrections following the method of Nelson and Clark 1973)].

Results and Discussion

Live trapping

During live trapping, we had 28 *Rattus tanezumi* captures in 1,471 corrected trap nights (1,884 total trap nights). Of these 28 captures, 26 captures were included in a mark-recapture analysis (2 individuals escaped before they could be marked). In total, we trapped 17 individuals (10 females and 7 males; 14 adults and 3 juveniles) of which we had 7 recaptures from 4 individuals. Average mass was 72.94 ± 7.23 g (95% CI = 58.77–87.12, $n = 17$).

Rattus tanezumi capture and recapture probability were best explained by models that included rainfall over the previous 24 hour period (Table 9). Capture probability increased with increasing rainfall ($\beta_{\text{rain24}} = 0.08 \pm 0.03$, 95% CI = 0.02, 0.15). Of the 7 individual covariates examined only the reproductive status of the individual (reproductively active > nonreproductive) was explanatory but the effect was weak ($\beta_{\text{reproductive status}} = 1.85 \pm 1.07$, 95% CI = -0.25, 3.94), as evidenced by the asymmetric confidence interval coverage (interval slightly overlapped zero).

Rainfall amount was also an important determinant of *Rattus* cf. *diardii* and *R. exulans* trappability elsewhere in the southern Mariana Islands (Wiewel et al. 2009, Yackel Adams et al. 2011). We speculate that the positive relationship between rainfall and capture probability may result from water stress. Surface water is typically rare or nonexistent (Mueller-Dombois and Fosberg 1998) in this region, which may lead to increased *Rattus* activity in association with rainfall events as they seek drinking water. Reproductive status was also an important contributor to *Rattus* cf. *diardii* trappability in the southern Mariana Islands. On those islands, as with Pagan, we observed higher capture probability for reproductively active individuals versus those that are non-reproductive; this could be a product of increased mate-searching movement associated with mating behaviors or more frequent foraging to satisfy the energetic demands of reproduction.

Mean maximum distance moved was 33.3 ± 2.8 m (95% CI = 27.7 – 38.8; $n = 4$). When combined with the nominal grid area of 1.56 ha, these MMDM estimates resulted in an effective trap area of 2.50 ha. The model-averaged *R. tanezumi* abundance estimate generated from our models equaled 40 ± 28 rats (95% CI: 17–96). Average rodent density was calculated to be 16 individuals/ha.

We observed no neophobia effect on capture success for *R. tanezumi* as we have for other *Rattus* species (*Rattus* cf. *diardii* and *Rattus exulans*) in this region. In other words, rats did not appear to be particularly wary and were just as likely to be trapped on the first night as on

subsequent nights. This could be a result of reduced rates of perturbation by humans on Pagan, which has been largely uninhabited for the past two decades.

Table 2. Model selection results for mark-recapture modelling of capture (p) and recapture (c) probability for *R. tanezumi* data collected on Pagan, 2010. Results include the relative Akaike’s Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i), number of model parameters (K), and model deviance.

Model	ΔAIC_c	w_i	K	Deviance
Rain24 + reproductive status	0.00	0.393	3	125.22
Rain24	2.34	0.122	2	129.63
Rain24 + neo2	2.53	0.111	3	127.75
Rain24 + CI	3.65	0.063	3	128.88
Rain48	3.73	0.061	2	131.01
Rain24 + sex	3.94	0.055	3	129.17
Rain24 + ear length	3.96	0.054	3	129.18
Rain24 + hind foot length	4.10	0.051	3	129.32
Rain24+ mass	4.30	0.046	3	129.52
Rain24 + head-body length	4.40	0.044	3	129.63

Snap trapping

During snap trapping, we captured a total of 14 *R. tanezumi* in 471.5 corrected trap nights (798 total trap nights). Catch per unit effort was highest in the *Casuarina* forest with a native forest understory (the same habitat type where live trapping occurred; Table 10).

Both live- and snap-trapping were consistent in that they resulted in low trap capture success. When combined with observations from visual surveys, these results imply that rodents are at moderately low densities on Pagan as compared to some of the southern islands. Much of the primary productivity of ground-level and understory plants on Pagan is removed by feral ungulates, which may limit food availability for rodents. The majority of the relatively few sightings of rodents during nocturnal visual surveys were of rodents foraging in fruiting trees, especially mango trees.

We did not find evidence of *M. musculus* or *S. murinus* on Pagan using either live- or snap-traps. However, there is no reason to expect that *M. musculus* could not establish or persist

on the island, given their stellar record of establishing on other islands around the world. The relatively low densities of skinks on Pagan might limit the abundance of *S. murinus* were they to become established, but shrews could probably make do by eating invertebrates (especially the cockroaches that are abundant on the island) and relying to a lesser extent on lizards. One of two long-term residents of Pagan stated that he had observed ‘very small rats’ (possibly *M. musculus*) around the old village, as well as small rats with high-pitched calls (*S. murinus*) around the landing strip. We trapped and conducted visual surveys in both areas and found no evidence of either species. Therefore, either these species are present and we did not detect them, they were present but populations have died out, or the observations by the island resident were not of these species. The observer spends part of the year on Saipan, where mice and shrews are common, so it is possible that he was confusing memories from Saipan with those from Pagan. Regardless, continued monitoring for the presence of these species would be valuable.

Genetic analysis

Genetic analysis of the mtDNA cytochrome oxidase I gene region of 29 *Rattus* indicated that all of our samples were most closely related to the *R. tanezumi* group described by Robins et al. (2007, 2008; S.J. Oyler-McCance and J. St. John, unpubl. data). We were intrigued by these results, as there appeared to be two distinct color/pattern morphotypes among the rats captured on Pagan. One morph appeared to be smaller with pelage that was typically a uniform grey, while the other was larger with darker (often brownish-red) dorsal pelage and light-colored ventral pelage (Fig. 25). Our current sample sizes preclude any conclusions on whether this apparent distinction is due to ontogeny, sex, or other contributing factors.

The single *R. exulans* known from Pagan is a wet (alcoholic) specimen at the National Museum of Natural History (NMNH 530819), collected near a ‘brackish lake’ (of which there are two candidate lakes on Pagan). This specimen is a juvenile, and a NMNH mammalogist told us, “My best guess, given that the specimen is a juvenile and in fluid, concurs with Andy's field ID, i.e. *Rattus exulans*. He also collected a series of *R. exulans* from Guguan Island, in a small island group just to the south of Pagan, and those too appear to be good *exulans*. All clearly differ from the large *Rattus tanezumi* that we have in abundance from the Mariana Islands” (D. Wilson, NMNH, pers. comm. 2010). If this specimen is indeed *R. exulans*, then either we failed to find existing populations on Pagan or the species is extirpated – genetic analysis of samples from the NMNH specimen could help resolve its species identification, while additional sampling effort on Pagan might resolve population status.

As discussed above, *R. tanezumi* and/or *R. rattus* appear to have been replaced by *R. diardii* in the large inhabited Mariana islands. Replacement of *R. tanezumi* does not appear to have occurred on Pagan, perhaps because this island receives few ships or aircraft in which *R. diardii* could reach Pagan from the southern islands. It is unknown whether *R. diardii* or *R. exulans* are any more or less harmful to native species as compared to *R. tanezumi*, but the three species tend to vary in body size (*R. exulans* tends to be small, while *R. diardii* tends to be the largest). As with many other potential invaders, development of biosecurity procedures for Pagan may reduce the risk of *R. diardii* or other exotic small mammals becoming established.

The timing of replacement of *R. tanezumi* by *R. diardii* in the southern Marianas is largely unknown. It may be that the ‘large *Rattus tanezumi*’ held in abundance at the NMNH (see above) are actually *R. diardii*. If so, and considering the size variation among the three

known species, then observers could be mistakenly assuming that mid-sized *R. tanezumi* are *R. exulans* simply because they appear different or smaller than the larger *R. diardii*. Revisiting the species identification (by morphological and/or molecular means) of preserved rats of Marianas origin could help resolve some of this confusion; until such time as these analyses and additional fieldwork are performed, we consider the rodent communities of most northern Mariana islands to be largely unresolved.

Our sampling effort was concentrated in relatively small areas on the northern half of Pagan – it is conceivable that other rodent species persist elsewhere on northern Pagan. Given that the southwestern peninsula is divergent in its reptile community, we consider rodent sampling on the peninsula to be an especially high priority for future research efforts. If rat species vary in their impacts on native plants or vertebrates, then determining the species of rats inhabiting other islands in the northern Marianas may be an important aspect of conservation planning for these islands.

Fig. 3. Two apparent morphotypes of *Rattus tanezumi* observed among rats captured on Pagan. Image above is of rat with uniformly grey coloration (including belly), while image below depicts rat with brownish-red dorsum and light-colored belly.



Table 3. *Rattus tanezumi* snap trap captures on Pagan (2010) based on Victor (N = 20), Museum (N = 10), and Mouse (N = 10) traps spaced at 10 m, 20 m, and 20 m, respectively. CPUE (catch per unit effort) based on 100 corrected trap nights.

Habitat	Dates sampled	Latitude	Longitude	<i>Rattus tanezumi</i>	Corrected trap nights	CPUE
Cliffline forest	28 June – 01 July	18.126	145.553	2	84	2.38
<i>Casuarina</i> with native forest understory	27 June – 30 June	18.120	145.764	6	98.5	6.09
Grassland	27 June – 30 June	18.116	145.767	1	123.5	0.81
<i>Casuarina</i> forest with abandoned buildings	04 July – 07 July	18.126	145.767	2	82	2.44
Native ravine forest	04 July – 07 July	18.120	145.76	3	83.5	3.59

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