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# Rodent-borne diseases in Thailand: targeting rodent carriers and risky habitats

Vincent Herbreteau[1], Frédéric Bordes[2], Sathaporn Jittapalapong[3], Yupin Supputamongkol[4], Serge Morand[2,5]

[1] Espace-Dev, IRD, Maison de la télédétection, Montpellier, France

[2] Institut des Sciences de l'Evolution, CNRS-UM2, CC65, Université de Montpellier2, 34095 Montpellier, France

[3] Faculty of Veterinary Sciences, Kasetsart University, Bangkok, Thailand.

[4] Siriraj Hospital, Mahidol University, Bangkok, Thailand

[5] UR22 AGIRs, CIRAD, Campus International de Baillarguet 34398 Montpellier, France

**Corresponding author**

Serge Morand,

Institut des Sciences de l'Evolution, UMR CNRS-IRD-UM2, CC65,

Université de Montpellier 2, F-34095 Montpellier, France

Tel +33 (0)6 88 50 57 13

serge.morand@univ-montp2.fr

**Abstract**

We developed a simple method to target rodent reservoirs in Thailand by using published studies screening microparasites in rodents from Thailand. Microparasite richness was correlated with both rodent sample size and pathogens' screening effort. The residual variation of this correlation helps at identifying major rodent reservoirs and potential risky habitats.

**Key words:** microparasite richness, rodents, Southeast Asia, zoonosis, habitat, prioritization.

**Running Title:** Targeting rodent-borne disease carriers in SEA

## Background

Targeting reservoirs of zoonotic diseases is a challenge particularly in countries presenting high biodiversity. Comparative analysis, which aims at investigating ecological and evolutionary patterns among species, may help at indentifying wildlife reservoirs using published studies.

## Introduction

We aim at presenting a simple way to prioritize reservoir species in relation to their capacity to carry multiple agents of potential diseases. We illustrate this simple method with rodent-borne diseases in Thailand, a country that showed major outbreaks of several rodent-borne diseases in the past years (1). We focused on rodents as carriers, vectors or reservoirs of numerous zoonotic diseases, notably microparasites (2). Thailand presents the advantage to harbour a rich biodiversity, although at threat (3), and to have been quite intensively surveyed

for rodent-borne diseases. Using published surveys investigating rodent-borne diseases in rodents in this country we aim at identifying the major rodent species reservoirs, at least in term of their capacity to host multiple pathogens. For this, we first investigate the relationship between the pathogen species richness observed among rodent species and the screening effort and, second, we use the residual variations of this relationship to prioritize rodents and evaluate the potential risky habitats.

## Materials and methods

We compiled surveys of microparasites investigated in rodents trapped in Thailand (from 27 references given in supplementary appendix). The data comprise a total of 17,358 rodents from 18 species of murine rodents that have been investigated for a total of 10 microparasites (Table 1). The microparasites were viruses, bacteria and protozoans. Viruses were: Hantaviruses, Lymphocytic choriomeningitis virus (family *Arenaviridae*, genus *Arenavirus*), Rabies virus and Hepatitis E virus. These viruses are directly transmitted between rodent hosts and are all major pathogens of humans. Three bacteria were investigated: *Leptopsira spp.* agents of leptospirosis, *Bartonella spp.* agents of bartonellosis and *Orientia tsutsugamushi*, the agent of scrub typhus. *Bartonella* sp. and *Orientia tsutsugamushi* are arthropod- borne agents, whereas *Leptospira spp.* are indirectly transmitted via contact with water or soils contaminated by urine of infected rodents. From the three protozoans, only *Toxoplasma gondii* can infect humans whereas *Trypanosoma spp.* and *Babesia spp*. infect livestock and more rarely humans. Altogether 1,716 rodents (10%) have been found positive for at least one pathogen. Microparasite richness was defined as the number of pathogen species for which each rodent species was found positive.

We used information on main habitats of rodents following Jittapalapong *et al.* (4,5), Ivanova *et al.* (6) and Suntsov et al. (7): forests, dry lands near forests, non-flooded lands, paddy fields and irrigated/flooded agricultural lands, houses.

**Results**

Total host sample size varies widely among rodent species, from 5683 *Rattus tanezumi* to 9 *Mus musculus*. This last species was removed from the analysis due to its low sample size. This great variability can be explained by the variability in abundance of each species but also by unequal sampling among habitats. All rodent species have not been screened for all selected microparasites, with number of pathogens investigated varying according among rodent species (Table 1). The detection of microparasites then depends on both the pathogens' screening effort (number of pathogens tested) and the host sampling size (number of individual hosts trapped and tested for a given microparasite).

Using multiple regression analysis between microparasite richness and host sample size and pathogens' screening effort as independent variables, we found that microparasite species richness was positively related to both independent variables ($P < 0.0001$, host sample size being log transformed). By investigating the residual variations among rodent hosts (Fig.1B), we show that several rodent species harboured more pathogens than that was expected by the regression model (i.e. positive residual values), particularly *Rattus adamanensis, Bandicota savilei, R. argentiventer* and *R. norvegicus*. Two species appeared to harbour less pathogen species than expected by the regression model (i.e. negative residuals values): *Mus cervicolor* and *M. caroli*.

Similar reasoning on habitats suggests that higher pathogen richness than expected from correlation with sampling effort (i.e. positive residual values) are found in non-flooded lands, forests and paddy fields.

## Conclusions

We have developed here a simple method for prioritizing/targeting rodents that are best carriers of rodent-borne diseases, in a sense that they harbour more pathogen species that expected on the basis of the relationship between pathogen richness and sampling effort. Controlling sampling effort in comparative analysis is usual as pathogen/parasite richness is highly correlated with the efforts done to sample their hosts. However, host sample size is also often positively correlated with some host features such as host density or host geographical range (8). A host living in high density and a wide geographical range is more sampled than a host living in low density and on restricted range. As parasite/pathogen richness is found correlated with host density and/or host geographical range (9-10), there are potential confounding effects between these host features and the sampling effort to detect these parasites/pathogens. Here, rather to determine the potential determinants of pathogen richness in rodents, which is a difficult task due to the lack of knowledge on many life traits of the species living in Southeast Asia, we used the residual variations of the pathogen richness / sampling effort relationship. Then, high residuals values mean high pathogen richness whatever the explaining factor. Interestingly, our results suggest some rodent species that are not commonly investigated to target for pathogen screening or surveillance such as *R. adamanensis* or *B. savilei*.

The second result suggest that non-flooded lands and forests should be more taken into caution, whereas much surveys focused on paddy rice fields and households, although for obvious reasons. There is growing empirical evidence that some ecosystems are prone to alter or improve parasite transmissions (11-13). The recent study of Duffy et al. (14) emphasizes that ecosystems with high productivity (and then high host densities) could select hosts for being more resistant to infections to limit epidemics and parasite transmission but also less

fecund (due to trade –offs between reproduction and immunity) compare to host living in ecosystems with low productivity. Assuming the reality of differences in pathogen richness between rodent species and the various habitats, our results call for future studies in Asian ecosystems to improve the processes prone to explain such patterns.

Finally the simple method developed here based on known research effort in pathogens' screening of wildlife can present some interest in surveillance prioritization (15) by allocating wildlife surveillance effort to specific rodent species in specific habitats.

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## Figure captions

Figure 1. Residual values in microparasite richness, corrected for rondent sample size and pathogens' screening effort, positively sorted according (A) to rodent species and (B) to habitats. High positive values of residuals in microparasite richness indicate higher species diversity of microparasites than expected by the regression modelling and can help at identifying "good" rodent carriers of pathogens or risky habitats, at least in term of high diversity of pathogens than can be encountered herein.

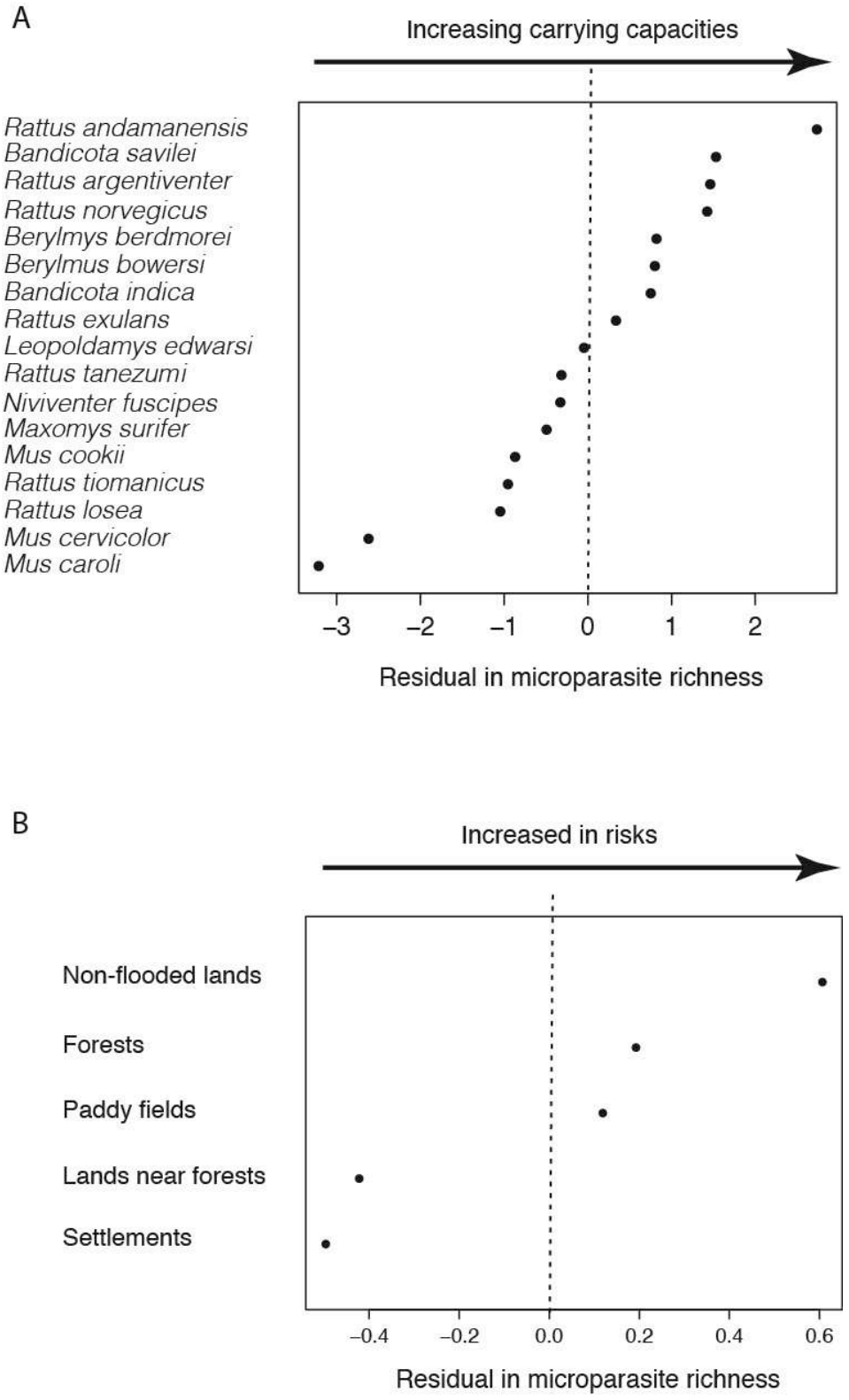
Table 1. Survey of infection by microparasites (viruses, bacteria, protozoans) of rodent species in Thailand, with number of positive individuals and number of investigated individuals between brackets (see references in supplementary materials)

| Species | *Leptospira spp.* | *Orientia spp.* | *Bartonella Spp.* | Hanta virus | Herpes virus | LCM virus | Rabies virus | *Toxoplasma gondii* | *Trypanosoma spp.* | *Babesia spp.* |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bandicota indica* | 102 (1006) | 101 (755) | 12 (167) | 60 (932) | 3 (164) | 20 (166) | 0 (276) | 1 (37) | 11 (192) | 17 (30) |
| *Bandicota savilei* | 12 (464) | 52 (189) | 2 (33) | 3 (197) | 2 (12) | 5 (14) | 0 (17) | 0 (11) | 13 (64) | |
| *Berylmys berdmorei* | 0 (6) | 2 (9) | 5 (20) | 0 (12) | | | 0 (3) | 0 (4) | 1 (23) | |
| *Berylmys bowersi* | | 0 (9) | | 0 (5) | | | | 0 (5) | 0 (3) | |
| *Leopoldamys edwardsi* | | | | | | | 0 (23) | 2 (16) | 4 (10) | |
| *Maxomys surifer* | | 0 (19) | 8 (33) | 0 (6) | | | 1 (150) | 2 (38) | 6 (22) | |
| *Mus caroli* | 0 (6) | 0 (69) | 0 (5) | 0 (67) | 0 (6) | 0 (3) | | | | |
| *Mus cervicolor* | 0 (12) | 0 (17) | 1 (2) | 0 (85) | | | | 0 (1) | 0 (13) | |
| *Mus musculus* | 0 (4) | | | 0 (2) | | 0 (3) | | | | |
| *Mus cookii* | | | | 0 (40) | | | | 0 (1) | 0 (17) | |
| *Niviventer fulvescens* | | 1 (4) | 0 (8) | 0 (10) | | | 0 (11) | 0 (13) | 0 (2) | |
| *Rattus andamanensis* | | 1 (12) | | | | | 0 (1) | 0 (7) | 1 (3) | |
| *Rattus argentiventer* | 6 (102) | 5 (23) | | 0 (107) | 15 (31) | 1 (9) | | | 4 (62) | |
| *Rattus exulans* | 48 (1242) | 20 (465) | 1 (71) | 24 (667) | 0 (3) | 3 (47) | 0 (1) | 1 (79) | 22 (266) | 0 (17) |
| *Rattus losea* | 6 (86) | 82 (638) | 2 (24) | 1 (119) | 0 (10) | 0 (2) | 0 (4) | 0 (1) | 3 (12) | |
| *Rattus norvegicus* | 179 (860) | 11 (36) | | 26 (309) | 22 (48) | 17 (54) | 0 (1) | 0 (34) | 1 (14) | |
| *Rattus tanezumi* | 107 (1858) | 542 (2284) | 7 (73) | 21 (900) | 5 (74) | 3 (69) | 0 (139) | 11 (256) | 7 (143) | |
| *Rattus tiomanicus* | | | | 0 (97) | 26 (105) | | | 0 (2) | | |

1

3 Figure 1

5


A
Increasing carrying capacities
Rattus andamanensis
Bandicota savilei
Rattus argentiventer
Rattus norvegicus
Berylmys berdmorei
Berylmus bowersi
Bandicota indica
Rattus exulans
Leopoldamys edwarsi
Rattus tanezumi
Niviventer fuscipes
Maxomys surifer
Mus cookii
Rattus tiomanicus
Rattus losea
Mus cervicolor
Mus caroli
−3
−2
−1
0
1
2
Residual in microparasite richness
B
Increased in risks
Non-flooded lands
Forests
Paddy fields
Lands near forests
Settlements
−0.4
−0.2
0.0
0.2
0.4
0.6
Residual in microparasite richness

**Supplemental file**
**References for the data on microparasites in rodents**

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